

THE OHIO JOURNAL OF SCIENCE

VOL. XXVIII

MARCH, 1928

No. 2

PRINCIPLES OF PLANT TAXONOMY, V.*

JOHN H. SCHAFFNER,
Ohio State University.

After studying the taxonomy of plants for twenty-five years the very remarkable fact became evident that there is no general correspondence of the taxonomic system with the environment, but as the great paleontologist, Williams, said in 1895: "environmental conditions are but the medium through which organic evolution has been determinately ploughing its way." Of course, the very fact that there is a system of phylogenetic relationships of classes, orders, families, and genera and that these commonly have no general correspondence to environment shows that, in classifying the plant material, we must discard all notions of teleological, utilitarian, and selective factors as causative agents of evolution.

The general progressive movement has been carried on along quite definite lines. The broader and more fundamental changes appeared first and are practically constant, and on top of these, potentialities or properties of smaller and smaller value have been introduced, until at the end new factors of little general importance alone are evolved. These small potentialities are commonly much less stable than the more fundamental ones and thus great variability in subordinate characters is often present in the highest groups. We must then think of the highest groups as being full of hereditary potentialities while the lower groups have comparatively few.

As stated above, there is a profound non-correspondence of the taxonomic system and the various orthogenetic series with the environment. The system of plants, from the taxonomic point of view, is non-utilitarian. The abundant adaptations of details to environment have no direct relation to the taxonomic

*Papers from the Department of Botany, The Ohio State University, No. 214.

system and do not run parallel with it. The same progressions take place whether a group is moving into the water or is remaining in the aerial environment. It is also self-evident that the most diverse taxonomic groups are adapted to and thrive in the same general environment. If there is, here and there, a correspondence, it is a mere coincidence, sometimes necessary for survival and sometimes not. Ecological adaptations, however, also appear in large groups of plants, as in the cacti and certain spurge, which fit well into a desert habitat although there is little similarity in their special fundamental morphology when compared with each other.

THE DETERMINATION OF LOWER AND HIGHER LEVELS IN THE SERIES.

In any series, the high types can be distinguished from the low because the low have a less complex heredity and a less complex reaction system when compared with the higher types. The relative position can also be readily determined by considering the degree of divergence of two or more types of homologous organs of the individual, as by comparing the floral axes and their peduncles and the inflorescence axes with the vegetative axes; or comparing sporophylls with foliage leaves. In a primitive lycopod or an araucarian the floral axis is very little different from a vegetative axis; in a *Magnolia* there is an appreciable difference; while in a poplar or sunflower the difference is enormous. The same comparisons would hold true for the sporophylls and foliage leaves in these types. Often a progressive series extends for a great distance from low to high forms, giving unmistakable criteria for judging the relative degree of advancement of any species or group; as, for example, the progressive development of a more definite and prompt determination of the floral axis in the case of strobili and higher flowers. In finding comparative levels, the sporophylls are often of great value. In the lowest levels there is no essential difference between the characters of these organs and the foliage leaves, except that the former bear sporangia, as in many lower Polypodiaceæ; while on a higher level, as in *Onoclea* and *Pteritis*, *Equisetum arvense*, or *Lycopodium complanatum*, the angle of divergence is comparatively great; although not nearly so great as in an angiosperm. One can also compare the diversity and divergence of vegetative branches to determine comparative levels in the progressive series; as,

for example the simple branching system of *Lycopodium lucidulum* with the polymorphic branches of *Lycopodium complanatum*. A progressive series is evident when one compares *Lycopodium annotinum* without inflorescence with *Lycopodium clavatum* and with *Lycopodium complanatum*. The evolutionary advancement is evident at a glance. A similar more extensive movement of inflorescence developments is shown in the gymnosperm series: *Araucaria imbricata*, *Cunninghamia sinensis*, *Cryptomeria japonica*, *Taxodium distichum*, *Ephedra trifurca*. One can find similar progressive series in a large number of monocotyl and dicotyl groups. If we compare the flowers and clusters of *Araucaria bidwillii*, *Magnolia foetida*, *Prunus americana*, *Salix amygdaloides*, and *Leontodon taraxacum*, we can easily see that the order given represents a very decided series of evolutionary advancement, and a correct presentation of their relative positions as high and low, when compared with each other without any reference as to their direct relationships. The order given represents the proper sequence of higher and more complex hereditary natures in respect to the structures under consideration. The same sequence would be indicated if in each case we would compare the degree of divergence between the sporophylls and foliage leaves. The difference in character between the floral axis and its peduncle and an ordinary vegetative axis will also indicate comparative levels very well. The difference in *Araucaria imbricata* is very slight, in *Magnolia foetida* not very pronounced, while in such an extreme form like *Populus deltoides* it is very great. This means then that the *Populus* cell has a highly complex heredity which in one case can bring out a thick woody vegetative stem and in the other a delicate, thread-like herbaceous stem represented by the pedicel and inflorescence axis. Any one can understand the implication when he remembers that in the most primitive vascular plants, like a *Lycopodium lucidulum* or a simple fern, all the branches are exactly alike in their hereditary expression. Such estimations of the degree of divergence of homologous structures in the individual are in general a correct measure of relative position. A *Lycopodium lucidulum*, *Magnolia*, and *Populus* would receive exactly similar treatment if their relative positions were judged by the degree of determination expressed in their reproductive or floral axes. A large number of such progressive differences can usually be discovered and it must always be remembered that it is the summation

of all the fundamentally important evolutionary processes which determines the relative position of a plant in the absolute scale. A plant is sometimes very advanced in one character and quite retarded in another.

In plants with flowers, the degree of promptness of determination of the reproductive axis usually gives very definite evidence of relative position in the progressive scale as indicated by the following examples: Staminate cone of Strobilophyta,—*Araucaria brasiliensis*, $1000 \pm$ stamens; *Araucaria excelsa*, $400 \pm$; *Pinus strobus* $200 \pm$; *Podocarpus spicata*, $70 \pm$; *Taxus canadensis* $7 \pm$; *Ephedra trifurca*, 5; *Gnetum latifolium*, 1. Monocotyl hypogynous series, Alismatales,—*Echinodorus cordifolius*, *Alisma subcordatum*, *Tenagocharis latifolia*, *Triglochin maritima*, *Triglochin palustris*, *Scheuchzeria palustris*, *Potamogeton natans*, *Althenia cylindrica*, *Naias flexilis*, *Zostera marina*. An hypogynous dicotyl series,—*Magnolia foetida*, *Ranunculus septentrionalis*, *Caltha palustris*, *Geranium maculatum*, *Agrostemma githago*, *Claytonia virginica*, *Anychia canadensis*, *Corispermum hyssopifolium*, *Monolepis nuttalliana*. An epigynous dicotyl series,—*Philadelphus coronarius*, *Nuttallia decapetala*, *Mentzelia oligosperma*, *Chamaenerion angustifolium*, *Ludwegia sphaerocarpa*, *Circaea lutetiana*, *Hippuris vulgaris*. All these lines and many others show the same remarkable orthogenetic series which is plainly the result of a continuously more prompt determination of the floral axis. This movement is even evident to some extent in the strobili of the Lepidophyta and Calamophyta. Such movements show no correspondence with the environment and all teleological explanations as selective value, interaction with the environment, or use and disuse have no scientific meaning, but belong to the childhood stage of biology. Correct ideas in regard to the evolutionary process are of the greatest importance in arriving at a proper phyletic taxonomy.

In the vegetative system there is a progressive movement in complexity of the branching system from the completely unbranched to a very extreme system and then a specialization from a moderately branched system to a comparatively simple condition, usually with the development of herbaceousness, and a progressive development of vegetative determination in some or all of the terminal buds of the plant. Commonly there are closely related woody and herbaceous forms in the same group, and larger groups are not to be segregated, merely on the basis

of woodiness and herbaceousness. These characters for the most part merely represent levels which are attained in a multitude of cases.

Although the secondary sexual condition is not manifest in the sporophyte until the heterosporous pteridophyte stage and the bisporangiate flower is carried through to the very highest group of dicotyls, nevertheless there is, all along the line, a progressive movement in very many branches from this condition to complete dieciousness. The movement is from sex determination at the end of the sporophyte ontogeny to earlier and earlier stages of the ontogeny until the limit is reached in the egg. The four general steps in this progression are: first, male and female determination on the same sporophyll; second, bisporangiate flowers, in the angiosperms with stamens below and carpels above; third, the various types and degrees of moneciousness; and fourth, the complete diecious condition which is, however, also developed in various degrees of completeness and intensity. There are exactly similar progressive movements in the gametophytes of the Homosporous Metathallophyta.

Progressive levels of complexity are also indicated by the diversity of leaf forms. In the lowest vascular plants like ferns and lycopods, there are but two types of leaves, foliage leaves and sporophylls, with practically no vegetative difference between the two. With the introduction of heterospory, there are at least three kinds of leaves. In cycads there are four kinds, in the lower Araucarians there are but three general kinds of leaves, while in *Pseudotsuga* there is a general tetramorphous condition. In the extreme Pinaceae, as in *Pinus*, there are beside the special juvenile leaves, two kinds of sporophylls one kind of foliage leaves, one kind of scale leaves on the dwarf branches, and two kinds of scale leaves on the ordinary branches. In some species these various categories will divide up into further subordinate types. In the gymnosperms the condition of the cotyledons follows along in the same general sequence. The lower gymnosperms have two cotyledons normally, while the number rises rapidly in the Pinaceae until it reaches a dozen or so in some pines. The development of specializations in the embryo is even more remarkable and attains its extreme expression in the bizarre embryogeny of the pines and certain of the Juniperaceae. Thus these parallel movements in the development of complexity of the hereditary

potentialities are correct criteria for judging the relative positions of the forms to be classified as high and low. Now it is true that occasionally a group may have retained with little or no change some very primitive structures in some part of its anatomy. Such a condition can, however, not be used to pull a species or group down to the lower level. Because a man may have retained the potentiality to produce gill-slits, either in the embryonic stage or up to the mature condition, does not put him on the level of a fish. The complexity of the hereditary potentialities as a whole will give the proper basis for a correct determination of any given case.

In the smaller branches of the phyletic system there are often quite definite orthogenetic movements resulting in definite orthogenetic series. In such cases the arrangements are to correspond to these movements. The sequence from low to high, from simple to complex, will then be properly indicated by the classification. Usually we cannot tell the actual sequence of origin of one form from another in such an orthogenetic series unless paleontological evidence is available. But the fact of the existence of an orthogenetic series is more important than speculations about its causes or the order of derivation of the members of the series.

THE DEFINITE LIMITS OF VARIOUS ORTHOGENETIC SERIES

It is evident, both from a consideration of various fossil groups and from a study of taxonomic series of living species, that many evolutionary movements come to a definite limit or end, beyond which no further advance is possible. In fact, practically all of the major movements are of this nature. The evolution of the time of sex determination proceeds backward through the ontogenetic cycle until it has progressed through both the gametophyte and sporophyte where the limit is reached in the diecious condition, when the circle is completed. The development of the flower progresses from the very slow determination of the primitive strobili until the highest stage is reached in the epigynous flowers in which the central growth of the flower axis stops before any floral parts have even made their appearance as incepts. In some of the higher *Andropogoneæ* a curious box is developed containing the grain. This box becomes more and more perfect until the extreme is reached in *teosinte*. In the *Liliales* the most primitive species are large trees, and many of the lines progress by successive steps

to smaller herbaceous forms, with the vegetative stem finally completely underground and only a few millimeters in height, all of the leaves and the flower clusters coming from below the surface. The dropping of stamens and other parts through the evolution of zygomorphy proceeds in the same way. Everywhere at the extreme limits, the flower has by successive stages arrived at the condition where only two or one stamen are left. The limit of development of the syncarpous gynecium is a unilocular ovulary with two stigmas or only one. The progressive limit in the relationship of sporophyte to gametophyte is the seed plant condition where the gametophyte is parasitic in the sporophyte and the sporophyte embryo is parasitic in the gametophyte. The recognition of these limits is of very great importance in taxonomic studies. Not only do the higher types approach evolutionary limits but in some cases "over adaptation" is brought about. The structure is carried far beyond the limits of practical utility, as for example, the parachute development in the fruit of the dandelion and others of the same family. The highly evolved plant is full of hereditary potentialities and thus often has enormous possibilities for minute variations when compared with the lower forms. The lower form has more of the primary heredity and usually little of the superficial while the higher contains all the primary properties and in addition a host of superficial and insignificant factors. These superficial factors are commonly transient or mutable, hence in many such high forms mutations are continually appearing. On the other hand some limits become remarkably stable.

EXTRAORDINARY DEVELOPMENTS APPEARING AT THE ENDS OF EXTREME PHYLETIC BRANCHES.

From what has been said in the preceding paragraph, it is evident that many extraordinary bizarre, and extreme developments will commonly be found at or near the evolutionary limits. Among such peculiar systems, the following are noteworthy: In *Azolla* the microsporangium develops a number of massulæ containing the spores and on the surface of these massulæ numerous anchor-like processes or glochidia are present. The higher Selaginellas present a very peculiar stem structure. There are tubular air cavities and the vascular bundles extend through the center of the tubes and are connected with the

ground tissue by means of filaments of cells or trabeculae passing across from the outside of the bundle to the wall of the air cavity. In the higher Pinales there is a remarkable system of multiple embryos with unusual suspensors as well as an extreme development of the number of cotyledons. In the *Pinus* embryogeny and also in *Biota*, we have a type of embryo development which is not duplicated in any other vascular phylum. In the Gnetales, the leaves of *Tumboa* present an extreme and peculiar system. The only two foliage leaves that the plant produces continue to grow from the base as long as the plant lives until they are ribbons, yards in length. The beginning of such a leaf development is also present in *Pinus* which belongs to the same phylum. But in even the most extreme cases of this character in *Pinus*, the basal growth continues for but a comparatively short period and the needles rarely reach a length of two feet. In the higher Helobiae, *Vallisneria* has developed a remarkable method of pollination in that the minute submerged staminate flowers are separated from the inflorescence to float on the surface, where they come in contact with the stigmas of the capellate flowers, which have been brought to the surface on an enormously long, spirally coiled peduncle. In the region of the highest grasses are the Indian corn (*Zea*) with its extraordinary stigmas, ear, and husks, and teosinte (*Euchlaena*) with its caryopsis packed up in a wonderfully constructed "alabaster" box, as recounted above, along with elongated stigmas and husks much like in its near relative. In the highest monocotyls, the orchids, one finds a host of remarkable developments, in the pollen masses, bizarre perianths, and often exceedingly peculiar leaf structures. Near the top of the Thalamiflorae are the violets, the highest of which present us with the problem of showy and cleistogamous flowers to the confounding of both Lamarckian utilitarians and Darwinian selectionists. These cleistogamous flowers as well as parthenogenetic developments of various types appear in the higher regions of many subordinate phyla. In the extreme Piperales we meet with 16-celled female gametophytes with their remarkable developments of multiple nuclear fusions, in one species of *Peperonia* the definitive nucleus being formed by the fusion of 14 polar nuclei. In the specialized Amentiferae, as in *Casuarina*, *Ulmus*, etc. chalazogamy has developed, representing the extreme condition of the evolution of the parasitic ability of the pollen tube. At the end of the Gentia-

nales stand the Milkweeds with extreme pollen specialization in evidence, again simulating the development in *Azolla* and the orchids. The method of pollination evolved in our common species, *Asclepias syriaca* is so efficient that with an ideal environment, with an abundance of insect visitors at hand, a milkweed flower has one chance in about 80 of being pollinated and thus contributing its service in the perpetuation of its race. The mints stand at the top of their order and the salvias at the top of the mints in progressive specialization of the flower. Now in the extreme species of *Salvia* two fertile half stamens are present in the flower which are so developed that they form a perfect brush and lever arrangement for spreading the pollen on an insect's back. This apparatus is one of the most remarkable in the plant kingdom, and the lucky *Salvia* would certainly be envied by its unlucky relative, *Asclepias*, if plants were able to experience envy at the good fortune of their neighbors. Near the top of the Scrophulariales stand the Bladderworts not only with highly evolved flowers but with their remarkable bladders or aquatic traps. Without multiplying examples further this list can be completed by a reference to the dandelion (*Leontodon taraxacum*) which stands about at the top of the plant kingdom. This plant has developed a type of parthenogenesis through the acquisition of some hereditary potentiality which interferes with the proper primary sexualization of its synaptic chromosomes; yet we all know how rarely a dandelion flower fails to set seed. Along with many of its relatives, the dandelion has evolved a peculiar, elongated neck at the top of its fruit which together with the pappus (which in itself is a remarkable structure at the end of calyx evolution) forms a most efficient parachute. Thus the dandelion, which has such a severe struggle to maintain itself in our front lawns and roadsides is able to send its offspring a hundred miles or so away from the paternal home where another favorable lawn or roadside may be available in which the child may possibly survive in a cruel and untoward world!

Now the recognition of these special developments is one of the most important exercises in taxonomy, because the more primitive members of any main or subordinate phylum rarely show extreme specializations except perhaps in very unimportant details. Curiously enough some of the conditions listed above have in the past been regarded as indicating primitive conditions, as the presence of chalazogamy in *Casuarina*, the extremely

advanced floral structures of Taxales, the multiple embryony and multiple cotyledons of Pinales, and the highly complex condition of *Zea* and its relatives. In fact there are yet few plant taxonomists that do not still place *Zea* at the base of the grass series. According to such a scheme, Indian corn must have been a special creation, without father, without mother, including all specializations and complexities, which after its placement on the earth gave rise to the series of lower and lower and more simple forms by devolution, each main step taken in the family leading nearer to the simple starting point of the lowest vascular plants. It is truly remarkable that such crudity of scientific concepts could be perpetuated until the present day and still be followed as the authoritative and orthodox faith of most of the taxonomists the world over. The older taxonomies, based on the old crude morphological conceptions and the teleological explanations of Lamarck and Darwin of the causes of evolution, as well as some of the newer systems which have not been emancipated from these notions, are so far from the reality that one actually finds that an entirely new beginning must be made if taxonomy is to be, as it should be, a systematization of our knowledge of the evolution of plants and a picture of the actual relationships. The new patch cannot be put on the old garment. The old bottles will not hold the new wine.

DISTINGUISHING PHYLETIC SEGREGATIVE CHARACTERS.

To distinguish fundamental segregative characters from progressive or merely detailed specializations is one of the main difficulties in taxonomy. As soon as one has advanced but a short distance in systematic botany, he is able to tell at a glance almost any of the thousands of members of such great families as, the sedges, grasses, orchids, legumes, mints, or composites. It must thus be that through all the multitudinous mutations which have resulted in subfamilies, tribes, genera, subgenera, species, and varieties something has remained which has not changed at all or only to such a slight degree that it is still recognizable. One of the chief exercises in phyletic taxonomy, therefore, is to ascertain these fundamental potentialities and characters, which because of their inherent stability give us our taxonomic system.

INDEPENDENCE OF THE VARIOUS MUTATIVE MOVEMENTS.

Although there is more or less parallelism in all movements going on in a phyletic line in a general way yet one series of possible advances may remain stationary while another advances rapidly even to the extreme limits. Thus it often happens that primitive and advanced characters appear side by side in the same species or group. This fact causes much confusion. There are also important progressive movements which originate in independent phyla at very diverse levels and in very diverse biological systems, in diverse environmental conditions. The origin of the flower or determinate reproductive shoot is of this nature. It appears in the homosporous level in two phyla while there are heterosporous pteridophytes which are entirely indeterminate, and among the gymnosperms, although a strobilus is mostly present in the living species, yet *Ginkgo* has come to a high evolutionary level with no determinate axes whatever.

PARALLELISM.

The parallel developments of both large and small degree are a constant source of uncertainty in taxonomy. Duplicate evolutions in different phyletic series are to be found in enormous numbers and frequently give rise to striking mimicries which have played such a prominent part in teleological explanations. But unfortunately for these crude utilitarian hypotheses, the duplications commonly occur without any relation to time or place, and even without similarity of ecological conditions. The older conceptions of selective mimicry belong to the same category as children's fairy tales, witch stories, and mother goose prodigies.

Parallelism necessitates distinguishing between characters that are segregative in kind, and characters which are merely corresponding stages in an orthogenetic series. For example, Orchidaceæ, Hydrocharitaceæ, Onagraceæ, and Campanulaceæ all have characteristically epigynous flowers, but the epigynous character which they have in common does not at all indicate relationship, but merely similarity of phylogenetic level. In the past, and to a large extent even in the taxonomic systems in vogue at the present time, such conditions are supposed to indicate relationship, as the character of the corolla, which is used to divide Dicotyls into apetalæ, choripetalæ, and sympetalæ, the apetalous forms being assumed to be primitive; but

one can find apetalous groups even among the Compositales. These three characters result from the progressive shortening of the floral axis, the choripetalous condition being the most primitive and the sympetalous and apetalous conditions more advanced stages due to earlier determination. In contrast to such characters that only indicate similar orthogenetic levels, true segregative characters are indicated in the fundamental branching systems of Lepidophyta and Ptenophyta. The first have dichotomous branching and the second monopodial branching. Such a difference is a true phyletic segregative difference between the two phyla, because the branching is brought about in a fundamentally different way in the two cases and the one is not higher than the other nor a derivative from the other but only a different way of accomplishing the same thing, namely, an increase in the number of growing buds and axes. Each system may and does evolve from an exceedingly simple branching system to a very complex one.

RECAPITULATIONS.

The partial or complete suppression of hereditary characters through the addition of new ones is of great interest to the taxonomist. For if such characters can be expressed for only a short period either as a normal process in the ontogenetic cycle or through the influence of some unusual environment which permits the suppressed potentialities to come into play, important evidence of obscure relationship may be obtained. The recapitulation may occur in the embryonic or juvenile phase of development, in a certain period of the mature ontogeny, or at the very end of the ontogenetic cycle. Many cases of undoubted recapitulations in the juvenile phase are known, as in some *Acacias* with phyllodes in the mature condition. The juvenile form regularly develops several, typical, compound leaves of the *Acacia* type. Recapitulation is seen at the end of the ontogenetic cycle in many flowers. In the grasses the vegetative phase develops a two-ranked leaf condition, but the ultimate floral axis invariably returns to the primitive three-spiral condition. In *Cabomba*, dissected leaves appear on the growing plant but at the very end, before the flowers appear, several minute vestigial, peltate leaves usually develop to proclaim its relationship to *Brasenia* and *Nelumbo*. In *Equisetum*, the leaves are degenerate and form a united sheath but the sporophylls appear as distinct structures, which is plainly a return to the condition of the *Equisetum* ancestors

with normally distinct leaves. In some plants recapitulations can be brought about by merely disturbing the normal functional gradients. In hemp, the several rejuvenations which can be brought about are always followed by the appearance of simple leaves, in the first stage of the new growth cycle in the same way as when the plant is developing from the seed. On the other hand, just as suppressed heredity may normally show only in the determinate, senile condition of the ontogeny so new heredity may be added to modify the character of the embryo or the juvenile phase. The embryo is subject to the same kinds of phylogenetic changes as the mature plant. Past opinion to the contrary has sometimes resulted in decidedly incorrect speculations as to relationships based on superficial similarities or dissimilarities of the embryos. But recapitulation when carefully considered is often an important aid in determining correct relationships. Recapitulation is made possible by the fact that most of the important new heredity is laid down on the old and may suppress the activity of the old or limit its activity to a special phase of the ontogenetic gradient. In some cases important new heredity may not show until near the end of a determinate gradient, as in the spikelets of *Cyperus* which have two-ranked glumes and flowers while the vegetative phase of the plant continues in the more primitive 3-spiral condition.

TRANSFORMED ORGANS.

How are we to conceive of the significance of a change in organs when, for example, the blade of a *Botrychium* develops one or more sporangia, which normally appear only on the stalk of the special sporangiophore? In the past morphology much speculation was based on such abnormalities since the plant was usually thought of as being built up of a certain number of homologous and diverse parts, just as a house is built up of boards, bricks, stones, etc. In the case cited the abnormality would have no more significance than that the functional gradient was disturbed through one cause or another and the cells brought into the condition where reproductive sporangium factors are brought into play. If the leaf normally present on a tulip peduncle is partly or completely transformed into a petal-like structure, it does not mean that the tulip formerly had petals where it now has leaves but merely that the functional gradient in the given peduncle arrived a little earlier at the condition in which petal factors normally come into play.

By disturbing the functional conditions in hemp it is easy to throw the sex of the carpellate plants to maleness in some branches and of the staminate plants to femaleness. In such cases it happens quite frequently that stamens appear with well-developed stigmas projecting from their tips. This does not mean that the ancestors of the hemp had stamens with stigmas. On the transition from vegetative to flower expression in a grass the two flowering glumes are developed, the lemma with a central midrib and the palet with two ribs. This does not mean that the palet represents two ancestral leaves or even sepals but simply that in the present system the floral axis is so shortened that the lateral organs appearing on the transition zone between the two-step to the three-step expression, partake of both conditions because the one set of factors has not become quiescent before the other is becoming active.

INTERPRETATION OF VESTIGES IN THE FLOWER.

Vestiges may appear in the flower due to vegetative reduction. Frequently the sporophylls at the tip of the cone are vestigial because the factors of determination come into play before the structures have had time to reach full development, as is to be seen prominently in *Equisetum* cones and in the carpellate cones of *Pinus*. Structures reduced through one cause or another may also assume special characters as the reduced glands or vestiges in the lower part of the andrecium of *Geranium*, *Pelargonium*, *Oxalis*, and *Linum*. The most prolific source of vestigial sporophylls in the flower is caused by displacement of the time of sex-determination. Since the primitive Angiosperm flower is bisporangiate with the secondary male state in the lower part of the axis and the secondary female state above, it follows that when the sex is determined somewhere below the flower, the given sexual state will then inhibit the development, to a greater or less degree, of the opposite type of sporophylls. A female state in the entire flower will interfere with normal stamen development and a male state will interfere with normal carpel development. Generally speaking, if the change is present in a low type of Angiosperm flower the vestiges will be large while in a high type they are frequently absent entirely. In some cases the stamen vestiges may be present and the carpels entirely suppressed, while in others the carpel vestiges may be present and the stamens completely suppressed. These vestiges, due to displacement of the time of sex determination, are commonly

of great importance in showing relationships, or lower and higher evolutionary levels. In some cases of monociousness or dieciousness, the flowers in one sexual state are on a much lower evolutionary level than those in the other sexual state, and these conditions may be of service in determining relationships. Of course, the complete suppression of the opposite set of organs in one flower and not in the other, as mentioned above, would come into this category. Very extreme cases are represented by *Cycas*, *Hydrocharis*, and *Cocos*. In *Cycas* the carpellate plant is a flowerless plant having an indeterminate reproductive axis, while the staminate plant is a flowering plant with definite, determinate staminate axes, or cones. In *Hydrocharis* the staminate flower is hypogynous with more numerous sporophylls and apocarpous carpel vestiges while the carpellate flower is completely epigynous with a syncarpous gynecium. In *Cocos* the staminate flowers have a nearly completely apocarpous andrecium of three vestigial carpels while the carpellate flower has a completely syncarpous gynecium. A common source of vestiges is found in the telescoping of vegetative and reproductive expressions associated with the progressive contraction of the floral axis. These vestiges are abundant at the base of the angiosperm flower as, for example, in the six or fewer perianth bristles of *Scirpus* and *Eleocharis*. Such imperfect developments of a less extreme type are prominent at the base of the carpellate cones in the higher species of *Pinus*.

HYBRIDIZATION IN EXTREME GROUPS.

In some of the more extreme genera, there is not only much mutation but the functional and morphological conditions are such that there is no barrier to free hybridization. This results in an almost endless multiplication of combinations and of frequent irregularities as well. The group of species or even the single species appears to break up into a fine spray of forms and combinations of characters. Such genera are represented by *Crataegus*, *Oenothera*, *Rosa*, *Salix*, *Hieracium*, *Zea*, etc. These complexes of species and varieties have been the despair of systematists as well as the seducers of the philosophically inclined geneticists and evolutionists, who have seen in such extreme conditions the very basis of evolutionary activity and genetic foundations. Evidently a special treatment of such genera and species would be desirable since they do not fit very well into the straight jacket of ordinary taxonomic procedure.

CLASSIFICATION AND CHROMOSOMES.

Larger and smaller groups commonly have a base number of chromosomes with haploid and diploid complements because of the processes of fertilization and reduction. So long as the number of chromosomes is similar there is no mechanical difficulty in perpetuating the results of a hybridization. But if the haploid complements are unequal in number, irregularities are the inevitable result, because in synapsis it is impossible to have a complete mating even though no incompatibility to pairing of chromosomes is present. The cytological study of a complex species or group of species is thus of great practical value. On the other hand, the mere shifting of chromosomes or the multiplication of the base number is of no fundamental taxonomic or evolutionary importance, although such mutation has probably been going on from the beginning of sexuality. Normally a proper balance is attained with efficient survival value, and the same base number may be commonly present in a wide diversity of related forms. The real evolution of plants which has resulted in the taxonomic system was through the addition of new potentialities in the structure of the protoplasm itself, presumably mainly in the structure of the chromosomes. The mere multiplication of the base number of chromosomes from the primary haploid and diploid normal to a triploid, tetraploid, or even greater polyploid number has little or no effect on the process of speciation, to say nothing of the great fundamental progressive and segregative processes which brought about the taxonomic system. Miss Blackburn has recently shown that a 16-ploid race of *Silene ciliata* can hardly be distinguished from a tetraploid race. The mere accumulation of chromosomes of like potentialities has no bearing on the evolution of new potentialities. It is the assimilative potentiality of the chromosome that must be changed. If such mutative changes have gone on or are continuing and no incompatibility exists to interfere with the primary sexual processes of either the normal union of the gametes or the synapsis of the chromosomes then hybridization with diverse mixtures of chromosomes may give rise to many new combinations with favorable selective value, resulting in diverse combination varieties, which would otherwise probably never come into existence. The supposed speeding up of mutations reported from the irradiation of certain plants and animals, although they may actually show a specific effect, which is

not at all certain since unfortunately the experiments have so far been tried only on the extremely complex species of *Drosophila* and *Nicotiana*, mean nothing fundamental either for evolution or taxonomy. Such claims of causing "evolution" or "speeding up" of the evolutionary process are not to be considered seriously, since the taxonomic system is of such a nature that no such simple and artificial influence is adequate to explain even the smallest steps of the process that brought it into existence. People who make such claims of causing or speeding up the evolutionary process simply show their complete innocence of the taxonomic system and the movements which are known to have been in operation during paleontological times. Such specious claims are of no value to the taxonomist because if even a chromosome can be injured or modified so as to destroy some of its important structures in which certain potentialities exist, such a fact will have no bearing on the serious study of ascertaining relationships of higher and lower order or of discovering the progressive evolutionary movements which have ploughed their way through the geologic eons.

SERUM REACTIONS.

One of the most remarkable discoveries in the realm of taxonomy in recent years is the fact that plant relationships can be correctly determined by means of serum precipitates. For this great development we are largely indebted to Mez of Koenigsberg. It is well known that in some plants the ordinary morphology is so obscured through reduction or specialization processes that a proper placement in the taxonomic system becomes very doubtful. In such cases, serum reaction determinations become exceedingly valuable and in fact indispensable. The serum method can also be used to check up on the phyletic system that has been developed through a study of the morphology, physiology and chemistry of plants in the classical way. The work accomplished so far confirms in a decided manner the phylogenetic relationships as worked out by Bessey, the writer, and others working purely with the morphological, physiological, and paleontological indications. Of course, the serum reactions probably have their obscurities as well as the morphological systems and are not to be taken as final arbiters in taxonomy. The practical taxonomy will always be built on a morphological foundation, since this is the easiest method of approach and is the only one that is commonly convenient to use.

STUDY OF THE FOOD OF THE BLUNT-NOSED MINNOW, PIMEPHALES NOTATUS.

WALTER C. KRAATZ,

Department of Biology, University of Akron.

INTRODUCTION.

Study of the food of minnows is now recognized as very important by ichthyologists. The public knows the importance of minnows as suitable, natural food for game fishes and other larger food fishes, but still fails to appreciate often the basic need of adequate food for the minnows.

Food of minnows has been studied by a number of investigators, practically beginning in this country with the widespread fish work of Forbes about 1880, as recorded in many papers. An example of recent work on food of several minnow species is that of Breder and Crawford, (1922). Many minnow species have been examined in general surveys, but few in large series of specimens. Studies referring to *Pimephales notatus* will be cited below.

Most of the specimens used in this study were seined in the Portage Lakes, near Akron, Ohio, a chain of lakes very popular for fishing and resort purposes, and rather typical of the few lakes of such sort in Ohio. (Osburn 1921).

General interest in the fish conditions of these lakes warrants investigation of their minnow food. Mr. E. L. Wickliff, of the Ohio Division of Fish and Game, suggested to the writer study of such species as would be abundant and good food for the game fishes, and likewise which would more likely be to a considerable extent vegetarian, so that they would be in little competition with the young game fishes. Such minnow species might then be suitable for propagation in fish hatcheries and fish ponds. *Pimephales notatus* (Rafinesque), the blunt-nosed minnow, was for practical reasons selected as best for this initial detailed study of food.

The writer wishes to express his indebtedness to Mr. E. L. Wickliff for suggestions, for some southern Ohio specimens, and for the collecting equipment furnished by the Ohio Division

of Fish and Game, and also his indebtedness to a number of interested students, who at various times in the summer of 1926 helped in the collections, namely Messrs. A. Dobkin, L. Sheinin, H. Cassidy, C. Krill, and also Mr. R. Rice, who helped in 1927.

DISTRIBUTION AND FREQUENCY OF THE SPECIES.

Pimephales notatus, recorded as the most abundant minnow in Ohio, (Osburn 1921), was the most abundant species of Cyprinidæ in every one of the Portage Lakes seined during the period of the collections, indeed nearly five times as common on an average as the next most abundant species, *Opsopoeodus emiliae*, which was followed closely by *Abramis*.

This is somewhat contrary to its distribution in Illinois, where statistical data (Forbes and Richardson, 1908, p. 99) showed it scarce in lakes and far commoner in creeks and small rivers, and in fact less frequent in lakes than 16 other minnow species.

The species lives chiefly over mud bottom, less frequently over sand bottom but also on stony shoals, where they breed, according to Reighard (1925, p. 226), who studied this species in a typical lake. The collections upon which this work is based certainly showed it to be an ideal small lake species.

PREVIOUS STUDY OF PIMEPHALES FOOD.

Forbes, (1878, p. 79) found three specimens "full of dirt with fragments of endogenous vegetation, confervoid algæ, and many diatoms."

Forbes, (1883, p. 73) found nine specimens from various parts of Illinois in which: "Mud made about eighty percent of the contents of the alimentary canal, the remainder consisting of unrecognizable vegetable debris, with a few filaments of algæ. Undeterminable insects occurred in one, and a single specimen of *Cypris* in another."

Hankinson, (1908, p. 204) says: "The food of this species varies very much, but consists chiefly of small organisms taken from the bottom, from water plants, and from the water. Individuals were frequently seen feeding on the eggs of the black bass, Johnny darter, miller's thumb and sunfish of three species." He noted that some of their own fry were eaten, and that in the spring "midges in various stages of development

formed the chief food." He also found some algæ and Entomostraca and in one case a beetle.

Forbes and Richardson, (1908, p. 120) state: "It is one of the mud-eating group, the alimentary canal being commonly packed from end to end with mud containing filamentous algæ and miscellaneous vegetable debris." Occasionally they found insect fragments and Entomostraca.

Reighard, (1915, p. 226) says: "the muddy bottom of protected bays affords it food, for it is a 'mud-eater.'" He also (p. 242) found a variable diet, indicating similarity to that given by Hankinson.

Pearse (1918, p. 271) in a study of this and many other species in Wisconsin Lakes, in commenting upon 60 specimens for which he studied the food in detail, said: "The blunt-nosed minnow eats a good deal of silt, bottom debris, and plants, though entomostracans and insects constitute more than half its food. Certain individuals had taken foods as follows: *Chironomus lobiferus* pupæ, 100; *Bosmina longirostris* cornuta, 100; oligochaetes, 98; filamentous algæ, 90; silt and debris, 100. These figures show that the minnow is a versatile feeder. The food in the stomach has always been chewed into fine pieces."

Pearse, (1921, p. 46) found in five specimens from Lake Pepin, rather equal quantities of midge larvæ, midge pupæ, *Daphnia*, fine debris, and unknown materials.

Thus considerable examination of food has been made in this common species. But a new survey here of over 300 specimens should give a better view of the variability of its diet, and give data from Ohio waters from which no such examination has been made before.

METHODS.

Food was examined in all cases from formaldehyde preserved specimens which had been collected near shore with a 15 foot, eighth inch mesh seine. The method of food study was the customary one, described by Forbes (1878), Pearse (1915, 18, 20), and used by others, as by the writer on *Campostoma* (Kraatz 1923). This is the method of estimation of volume of each class or type of food, expressed in percentage of the whole food contents of each fish. No quantitative work was done. This qualitative method gives by mere inspection and

judgment, obviously only approximations of correct percentages. But with care and use of many specimens the approximations become as reasonably accurate as can be expected, and it is the only simple, feasible method available. The worst difficulties are in cases where masses of commingled inorganic and finely divided organic debris must be differentiated for estimates, and where percentages are judged on some large mass, say of a larva of some thickness, over against numerous tiny diatoms or algæ scattered over a wide area. Food items occurring in large quantities were expressed commonly in multiples of tens or fives. But relatively rare items were often apparently correctly expressed as one per cent or two per cent. It must be understood that the numerous fractional percentages, expressed to one decimal point, occurring in the tables, were secured only after averaging groups of individual specimens.

Altogether 315 specimens of the species were carefully examined. In each the entire alimentary canal in the abdominal cavity was taken, measured, cut into pieces and the entire contents squeezed out upon a large glass plate. The mass was evenly spread over the plate in a film of water, and examined with binocular first under X 29, and then X 46, which was adequate to show up most foods and estimate the contents in general, and then examined under low power of compound microscope, usually no more than X 75, which was required to recognize the groups of smaller organisms such as diatoms, and other unicellulars. Although some greater magnifications were used for some minute organisms, it was not necessary for the work presented in this paper.

EXPLANATION OF TABLES.

The detailed findings of food items of all 315 individuals of the species are not given in tables in this paper; they would fill at least 15 pages of tables. In grouping specimens, and averaging foods of a common kind together for all fishes of a group, it was so arranged that in each group (or each entry in the table) there would be fishes from only one lake and one collection, and also of only a small range of lengths. Much space is saved, though countless, detailed diet differences are partly obscured.

In one table (No. 4) a few individuals are selected showing particularly contrasting individual diets.

In reading food percentage figures, there may come inevitably the impression of relative quantities of foods. Naturally this is incorrect. To assist in a corrected idea there should be noted in this connection the figures expressing to what degree the intestine was filled. In all individual specimen data, the writer has intestine length as well as "degree filled" to correlate with length of fish. "Degree filled" is an estimation; if "1" is used, it means the intestine was packed from end to end; if " $\frac{1}{2}$," that it was about $\frac{1}{2}$ full, no matter how distributed. In grouping the fishes the fractions can tell no more than, when for instance the figures $\frac{1}{4}$ — $\frac{3}{4}$ occur for 10 fishes, that some of the ten had as little as $\frac{1}{4}$ and other as much as $\frac{3}{4}$ of the intestine filled.

ABBREVIATIONS USED IN THE TABLES.

New (New Reservoir); Nesm. (Nesmith Lake); Long (Long Lake); West (West Reservoir); East (East Reservoir); Turk. (Turkeyfoot Lake); Rex (Rex Lake); S. O. (Southern Ohio, from the Ohio River drainage, but with exact localities for specimens examined unknown. This group was sent to the writer by Mr. Wickliff). In one place in Table 2, an entry of two lines is recorded as "East S." This stands for East Reservoir, Sandy Beach. The latter, a sandy bathing beach, was just one particular collecting place very readily worked, among others on the lake. But it happened that specimens were kept separated from those of other localities on the lake, and incidentally showed some interesting differences in detail of food from most of the fish from other collections.

TABLE I.
Alimentary Canal Contents of *Pimephales notatus*.

Date of Collection	Locality Collected	Fish Length, mm.	Number of Specimens	Degree Filled	Inorganic	Unrecognizable Organic Debris	Coccogoneales	Hormogoneales	Diatoms	Protococcales	Desmids	Filamentous Green Algae	Higher Plant Remains	Protozoa	Rotifers	Setae, Annelida	Statoblasts, Bryozoa	Copepoda	Cladocera	Ostracoda	Amphipoda	Water Mites	Eggs (unknown)	Caddis Larvae and Cases	Midge Larvae	Insect Remains	Unrecognizable Animal Remains
6-24-26	New	40-55	7	$\frac{1}{2}$ - $\frac{3}{4}$	11.0	6.7	2.3	8.0	.7	1.7		9.3						38.9	1.4						11.4	5.7	
6-29-26	"	37-49	2	$\frac{1}{2}$ - $\frac{3}{4}$	15.0	15.0	2.5		2.5	2.0		1.0	2.5	1.0				3.5							15.0	40.0	
"	"	50-58	7	$\frac{1}{3}$ - $\frac{3}{4}$	23.7	18.0	2.3		5.7	4.1	.4	6.7	.7	3		.3	.1	.4	6.6	.1					10.8	19.8	
7-15-26	"	21-29	10	$\frac{1}{10}$ - $\frac{1}{2}$	5.3	6.3	.5		5.0	3.5	.1	1.8		.3		1.4	7.0	13.3	4.3						50.5		.7
"	"	42-49	4	$\frac{2}{3}$ - $\frac{3}{4}$	17.5	12.5	.5		13.5	21.2	2.5	13.3	1.2					1.5							16.3		
"	"	50-55	6	$\frac{1}{3}$ -1	17.0	9.0	2.0	.8	10.2	14.5	.8	1.3	1.7				.5	17.2	15.0						8.3	1.7	
7-29-26	"	28-35	10	$\frac{1}{4}$ - $\frac{7}{8}$	15.3	22.0	.4	6	4.8	6.3	1.4	2.0		.4			2.5	5.0	10.0	17.5			.6		6.2	4.0	1.0
"	"	50-54	5	$\frac{1}{2}$ - $\frac{3}{10}$	17.0	25.0		.2	13.8	18.0	2.2	.4	4.0	.4				12.0	5.0			1.0			1.0		
"	"	60-63	5	0- $\frac{1}{10}$	7.5	8.7	.7	.5	4.0	12.3	.3	1.7		.3	.3			8.7	32.5	22.5							
7-2-27	"	35-46	3	$\frac{1}{2}$	1.3	10.0	.7		3.3	.7		.7						1.6	65.0	5.0					11.7		
7-6-26	Nesm.	41-47	2	$\frac{1}{10}$ - $\frac{1}{4}$	42.5	15.0			.5							.5											1.5
"	"	51-60	3	$\frac{1}{2}$ - $\frac{1}{4}$	23.3	25.3		1.0	3.7	.3		2.0	1.0					41.7	1.7								
7-20-26	Long	36-43	7	$\frac{1}{10}$ - $\frac{1}{2}$	8.9	14.4	.3		.1			4.3				.1		10.0	2.1	50.7					2.9	5.7	.7
"	"	44-49	10	$\frac{1}{3}$ - $\frac{3}{4}$	13.2	14.5	.8	.6	.6	.3	.2	1.3	5.3			.5		2	6.0	27.5					3.0	25.5	.5
"	"	50-56	10	$\frac{1}{10}$ - $\frac{1}{2}$	13.7	13.3	2.4	.9	3.7			2.0	16.7			2	.5	1.0	9.0	9.0	5.0		1.0		12.5	8.0	1.0
"	"	61-64	3	$\frac{1}{2}$ - $\frac{1}{2}$	15.0	20.0	5.7	1.3	7.0			3.3	24.3					13.4	3.3							6.7	

TABLE II.
Alimentary Canal Contents of *Pimephales notatus*.

Date of Collection	Locality Collected	Fish Length, mm.	Number of Specimens	Degree Filled	Inorganic	Unrecognizable Organic Debris	Coccogoneales	Hormogoneales	Diatoms	Protococcales	Desmids	Filamentous Green Algae	Higher Plant Remains	Protozoa	Rotifers	Setae, Annelida	Statoblasts, Bryozoa	Copepoda	Cladocera	Ostracoda	Amphipoda	Water Mites	Eggs (unknown)	Caddis Larvae and Cases	Midge Larvae	Insect Remains	Unrecognizable Animal Remains
7-20-26	West	24-29	10	$\frac{1}{8}$ - $\frac{3}{4}$	12.5	11.5	16.6	1.2	4.9	5.0	1.3	4.7	.3	.3	1.0	4.3		1.0	7.6	27.0			.3				.5
8-5-26	"	33-48	6	$\frac{1}{4}$ - $\frac{3}{4}$	15.8	16.5	9.2	1.7	7.6	.3	2.3	3.8	2.5	.2				5.0	17.5	13.4			.8		.8	1.7	.8
"	"	50-56	10	$\frac{1}{8}$ - $\frac{1}{2}$	19.6	23.6	8.3	2.2	6.8	.5	2.0	6.0	4.4	.1	.1	1.0		.5	4.0	17.4				2.0	1.0	.5	
"	"	58-61	4	$\frac{2}{3}$ - $\frac{1}{2}$	15.0	19.5	1.5	.5	2.2		1.8	3.8	3.8				1.2	3.2	30.0					13.7	3.8		
6-26-26	East	40-66	5	$\frac{1}{2}$ - $\frac{3}{4}$	17.0	11.6	.4	.4	15.0	.2		.8	2.0					3.8	.4	4.0		1.0		12.4	28.0	3.0	
7-3-26	"	42-54	6	$\frac{1}{2}$ - $\frac{3}{4}$	20.8	14.2	6.1	7.3	23.8	1.5	.3	3.1	1.6	.3			.5	2.6	17.5								
7-17-26	"	44-49	5	$\frac{1}{2}$ - $\frac{9}{10}$	15.0	7.0	6.2	23.4	21.0	.4	2.0	2.0	1.2	.4				.4	8.8	10.0			.2		2.0		
"	"	50-58	12	$\frac{1}{2}$ - $\frac{1}{2}$	14.3	6.5	10.5	10.5	34.2	2.5	5.5	8.0	.4	.2				.3	4.7	.8				.4	8.4	.4	
"	"	62-63	3	$\frac{3}{4}$ - $\frac{9}{10}$	15.0	4.3	6.3	12.7	25.0	1.3	1.3	9.0	2.7	.7				5.0					16.6				
7-17-26	East S.	48-58	10	$\frac{1}{3}$ - $\frac{1}{2}$	13.8	4.7	1.8	4.0	6.5	.3	.4	2.5						65.5								.5	
"	"	61-71	10	$\frac{1}{2}$ - $\frac{1}{2}$	15.8	4.0	2.2	13.1	4.3	1.1	.5	2.9					.3	.3	53.0	1.2						1.3	
7-31-26	East	25-36	12	$\frac{1}{2}$ - $\frac{3}{4}$	16.3	17.5	4.4	2.1	4.3	.1	1.3	4.8	9.3		.3			3.8	17.1	15.8		.7	.3	.7	.8	.4	
"	"	40-48	8	$\frac{1}{2}$ - $\frac{3}{4}$	20.3	14.4	7.3	2.5	2.3		.8	1.8	6.2						3.5	40.6							
"	"	50-58	6	$\frac{1}{3}$ - $\frac{1}{2}$	16.7	20.8	1.2	3.3	3.3	.2	.5								5.0	23.3				.8	6.7	1.3	
"	"	60-69	4	$\frac{1}{2}$ - $\frac{3}{4}$	18.2	20.5	2.0		5.8						.5			1.0	18.8	1.3				6.2	17.5	1.2	
8-5-27	East	24-36	10	$\frac{1}{2}$ - $\frac{1}{2}$	1.1	15.2	3.3	3.2	2.5	.1					.3	.9	.7	13.5	31.5	9.5				11.0	8.5	1.6	

TABLE III.
Alimentary Canal Contents of *Pimephales notatus*.

Date of Collection	Locality Collected	Fish Length, mm.	Number of Specimens	Degree Filled	Inorganic	Unrecognizable Organic Debris	Cocconeales	Hormogoneales	Diatoms	Protococcales	Desmids	Filamentous Green Algae	Higher Plant Remains	Protozoa	Rotifers	Setae, Annelida	Statoblasts, Bryozoa	Copepoda	Cladocera	Ostracoda	Amphipoda	Water Mites	Eggs (unknown)	Caddis Larvae and Cases	Midge Larvae	Insect Remains	Unrecognizable Animal Remains
7-10-26	Turk.	42-49	8	0- $\frac{3}{4}$	12.1	17.1	6.9	6.6	5.6	1.7	.4	6.6	.7		.2	.4		1.6	24.0	10.4						4.3	1.4
"	"	50-58	10	$\frac{1}{8}$ - $\frac{3}{4}$	15.3	13.8	4.3	2.2	.8	.6	.1	3.5	13.5	.2				9.0	16.9	5.5	.5	.2	.6		3.5	9.0	.5
"	"	61-62	2	0- $\frac{1}{4}$	15.0	10.0	10.0	5.0											20.0							40.0	
7-24-26	"	40-49	9	$\frac{1}{8}$ - $\frac{2}{3}$	15.6	22.2	15.8		3.1	1.1	.6	10.0	5.5						19.3						3.9	2.5	
"	"	50-57	6	$\frac{1}{5}$ - $\frac{5}{6}$	24.2	21.7	7.8	2.0	3.0	.8	.3	10.0	8.3		.2			.8	5.5	5.0					3.4	6.7	
"	"	60-65	5	$\frac{1}{2}$ - $\frac{2}{3}$	19.0	17.0	6.6	.6	4.8	1.2	3.4	39.0	2.6		.2			1.0	4.6								
8-7-26	"	34-38	5	$\frac{1}{4}$ - $\frac{1}{2}$	11.0	18.0	23.6		1.2			2.6						1.0	17.0	9.0					9.0	3.0	4.6
"	"	47-57	5	$\frac{1}{4}$ - $\frac{4}{5}$	26.0	41.0	8.0		6.0	.6	4	2.0	2.4						3.0	2.0					3.0	1.0	
7-24-26	Rex	30-35	5	$\frac{1}{4}$ - $\frac{2}{3}$	11.0	18.0	6.2		8.4	5.2	6.4	15.0	1.6		.2			3.0	6.0						15.0	2.0	
"	"	44-49	5	$\frac{1}{4}$ - $\frac{3}{10}$	15.0	23.0	8.0		4.5	2.6	5.0	6.0	3.0	.2		.2		1.0	15.6	2.0					3.0		
"	S. O.	21-27	7	$\frac{1}{3}$ - $\frac{4}{5}$	40.4	25.7	1.1		9.6		5.7	1.2	.7	.2				.7	11.4								
"	"	30-39	10	$\frac{3}{4}$ -1	66.5	25.0			1.4	3.6		1.6	1.3	.3	.1												
"	"	40-48	8	$\frac{3}{8}$ -1	57.5	11.4	1.5	16.1	8.6		.5	3.6	.5	.3													
"	"	50-59	9	$\frac{1}{8}$ -1	59.7	10.6	1.4	14.8	4.0		.7	5.0	2.1					.1								5	
"	"	60-71	6	$\frac{1}{8}$ -1	55.8	16.7		5.4	2.3	.7	.2	8.2	1.2		.2	.2			3.3						1.6	.6	3.3

DISCUSSION OF THE FOOD.

As seen in the tables, inorganic material was found in large amounts in canal contents. Rarely was there a fish without at least a small percentage. On the other hand it was not exceptionally high, averaging from 10 to 30 percent in Portage Lakes fishes. That much might be expected of any fish feeding in shallow water, over muddy bottom, and inclined to a somewhat bottom feeding habit, without its being properly characterized a "mud-eater." In the series of specimens sent by Mr. Wickliff from southern Ohio, (from some parts of the Ohio River drainage) there was a considerable contrast, for inorganic matter was present to a greater amount than 50% on an average. The smallest percentage, 15% to 20% was found in only a few of forty fishes, and several had as much as 90% inorganic matter.

Unfortunately the "unrecognizable organic debris," was often of large percentage. None of this so listed could be distinguished with any certainty whatever. Sometimes it was even hard to separate from inorganic matter, but on close examination showed clear differences from mud particles or crystals, appearing usually as flocculent, irregular bits, finely broken down material, sometimes of greenish color, suggesting that it was often of plant origin. Animal material would most likely be more quickly and fully digested if once sufficiently mechanically broken down, and thus escape discovery.

There were many different plant types. "Higher plants" means that in various specimens pieces of leaf, etc., of seed plants presumably, were found. They may have been small pieces when ingested. In several series of specimens, where there is a rather large percentage, as from East Reservoir, July 31, 1926, and Long Lake, July 29, 1926, it was almost entirely due to the presence of *Wolffia* in large numbers.

Coccogoneales (unicellular blue-green algæ) and Hormogoneales, (filamentous blue-green algæ), as well as diatoms and Protococcales, (unicellular green algæ and some colonies) were usually easily recognizable by group, and not much digested, that is when recognizable at all. Filamentous green algæ usually occurred in fragments.

In many specimens the total plant food percentage was large, but in almost as many other specimens, the animal food was in excess. In the literature there has been somewhat more reference to its preference for plant food, possibly giving rise

to the idea (together with its possession of a rather long intestine), that it must be vegetarian. Some writers however show its very general diet. The present study does not allow its classification as vegetarian, for the following reasons: the large percentage of animal food frequent, and the unusual prevalence of algæ which it had to draw upon for food.

In explanation of the latter point, it should be noted that during the time of the collections, particularly in the latter half of the summer, of both years, there were found present, particularly in East, West, and New Reservoirs, and also Turkeyfoot lake, tremendous quantities of minute algæ in the plankton, giving to the water a prominent greenish color. This was found to be due to blue-green algæ, of both filamentous types, and tiny floating colonies of cells, like *Coelosphaerium* and *Microcystis*. Much collecting was done with tow net, and in the time of greenish water, every drop contained many of these blue-green algæ. All other types, both plant and animal, were relatively rare in this plankton. A real vegetarian fish like the gizzard shad, (Tiffany 1920, 21), would have found this a bounteous feast, and would have been filled with these algæ. It should be noted that in shallow water these algæ were equally prevalent throughout, surface to bottom, where a foot or up to three feet deep, in the very water where the blunt-nosed minnows were collected, which, (except in few individual cases) had eaten relatively much less of the algæ then were present in the water. *Pimephales* seems to be partly a bottom feeder, though not so much as is *Campostoma*, (Kraatz 1923).

Animal food was found to be of many types. Unrecognizable animal remains were noted in only a few specimens. But certain kinds of much broken down animal remains may be so readily digested so as to escape listing.

The vast majority of animal organisms were very small. The record for Protozoa and rotifers is probably incomplete.

Entomostraca formed the outstanding animal type of food. Cladocera were most abundant in the largest number of specimens, and seemed to be eaten in large numbers whenever common. In possibly half of the cases they were quite intact, but the rest could be recognized only from antennæ, pieces of shell, or the ephippium. A number of specimens had 80% and more, and one 95% Cladocera. Ostracoda were nearly as common, though in somewhat fewer fish. In some they formed a large percentage, including several with 80% and one nearly

90%. They were usually much broken up. Copepoda occurred in a few fishes, much broken up. In the rare cases where Amphipoda were listed, Hyalella was found broken up considerably.

The largest recognizable animal types were the insects, though Hyalella, mentioned above, was as large as most insects, since on the whole only smaller insects were eaten. In a few cases where adult insects were found they were much disintegrated. Midge larvæ were far in excess of all other insects. In many instances they were quite intact, and practically in all cases recognizable as midge larvæ. Often the entire chitin covering was found. The larvæ were all very small, and only twice was one over 5 mm. found in the food.

No recognizable fish remains were found. As for eggs eaten, in a number of specimens some eggs were found, all grouped in the tables as "eggs (unknown)." Some of these were insect eggs. One fish only had eaten fish eggs (likewise recorded in same column), forming 5% of its food. Unless there were many fish eggs well digested, Pimephales has a good record on that score, offering a contrast to the findings of Hankinson (1908). On the whole there was less food disintegration than one was led to expect from findings of Pearse (1918).

CONCLUSIONS

In view of the striking prevalence of algæ in the waters, with a lesser ingestion of these algæ than a real vegetarian would show, and in view of the large proportion of Entomostraca taken, it seems that Pimephales is as much an animal feeder as plant feeder, if not more so. It is impossible to say that the species has any food preferences, and also impossible to show that the blue-green algæ were for any reason somehow repellent, or that other algæ would be taken in preference to blue-greens, if present.

Pimephales is best regarded as a general feeder, preferring all small food organisms, and as a fish versatile in a high degree, as has been shown more or less also in previous studies, principally by Pearse (1918). It is not characteristically vegetarian, nor carnivorous, nor specifically a plankton feeder, but a general feeder upon all small organisms and debris taken about equally from plankton and from the bottom of its habitats.

Since Pimephales notatus is by far the most abundant minnow, at least in the Portage Lakes, and very generally common in Ohio, it is one of the most outstanding food for the

game fishes of the region. Also, this natural food species, since it thrives so well, will undoubtedly increase somewhat more under general regulation of minnow seining. This increase comes without extra cost. While this minnow is not a vegetarian, as indeed very few species are, it is not much in competition with game fishes for food, except in the very young stages of the game fish life. It certainly is not harmful because not carnivorous on such young. Pimephales should therefore be one of the minnows most favored, and should be found desirable for various fish ponds and lakes.

BIBLIOGRAPHY.

- BREDER, C. M. JR., AND CRAWFORD, D. R.
 1922. The food of certain minnows; a study of the seasonal dietary cycle of six cyprinoids, with special reference to fish culture. *Zoologica*, Vol. II, No. 14, pp. 237-327.
- FORBES, S. A.
 1878. The food of Illinois fishes. *Bul. Ill. State Lab. Nat. Hist.* Vol. I, No. 2, pp. 71-86.
- FORBES, S. A.
 1883. The food of the smaller fresh-water fishes. *Bul. Ill. State Lab. Nat. Hist.*, Vol. I, No. 6, pp. 61-86.
- FORBES, S. A., AND RICHARDSON, R. E.
 1908. The fishes of Illinois. *Illinois State Nat. Hist. Survey Div.* (2nd ed. 1920), pp. cxxv. and 357.
- HANKINSON, T. L.
 1908. A biological survey of Walnut Lake, Michigan. *Geol. Survey Mich.*, 1907, pp. 157-288.
- KRAATZ, W. C.
 1923. A study of the food of the minnow *Campostoma anomalum*. *Ohio Jour. Sci.*, Vol. XXIII, pp. 265-283.
- KRAATZ, W. C.
 1924. The intestine of the minnow *Campostoma anomalum* (Rafinesque), with special reference to the development of its coiling. *Ohio Jour. Sci.*, Vol. XXIV, pp. 265-298.
- OSBURN, R. C.
 1901. The fishes of Ohio. *Ohio State Acad. Sci. Sp. Paper* 4, pp. 104.
- OSBURN, R. C.
 1921. Report on fish conditions in the Portage Lakes. *Div. of Fish and Game, Ohio Dept. Agri., Sportsmen's Bul.* No. 1, pp. 14.
- PEARSE, A. S.
 1915. On the food of the small shore fishes in the waters near Madison, Wisconsin. *Bull. Wis. Nat. Hist. Soc.*, Vol. XIII, No. 1, pp. 7-22.
- PEARSE, A. S.
 1918. The food of the shore fishes of certain Wisconsin Lakes. *Bul. U. S. Bur. Fisheries*, Vol. XXXV, (for 1915-16), pp. 245-292.
- PEARSE, A. S.
 1921. The distribution and food of the fishes of three Wisconsin lakes in summer. *Univ. Wis., Studies in Sci.*, No. 3, pp. 1-61.
- REIGHARD, J.
 1915. An ecological reconnaissance of the fishes of Douglas Lake, Cheboygan County, Michigan. *Bul. U. S. Bur. of Fisheries*, Vol. XXXIII, (for 1913), pp. 215-249.
- TIFFANY, L. H.
 1920. The gizzard shad in relation to plants and game fishes. *Trans. Amer. Fish. Soc.*, 1921, pp. 382-386.
- TIFFANY, L. H.
 1921. Algal food of the young gizzard shad. *Ohio Jour. Sci.*, Vol. XXI, pp. 113-122.

A SURVEY OF RATES OF WATER LOSS FROM LEAVES.*

GLENN W. BLAYDES,

Department of Botany, The Ohio Wesleyan University.

INTRODUCTION.

This paper is a record of data collected showing water loss from leaves from a number of plants growing in several habitats. As many different species as possible were tested in the time at the writer's disposal. At first a mere list of water loss data was intended, but a number of new phases have arisen during the course of the tests. It is probable that, as the work progresses and more is known about the general field, still others will arise.

Representatives of three of the four great groups of plants have been studied, namely from the Spermatophytes (including both Angiosperms and Gymnosperms), Pteridophytes and Bryophytes. The greatest number is from the Spermatophytes since they make up such a large proportion of our vegetation. The method used in collecting data was not applicable to the Thallophtyes and submerged aquatics.

In collecting these data, representatives were selected from several different habitats so that comparisons of their water loss might be made. An attempt has also been made to study the diurnal rates of water loss from a small number of plants.

The water loss from plants has an extremely important bearing on their distribution and their survival. Heretofore, largely because of their economic importance, much more has been done with agricultural plants in this relation than with other types. And too, in nearly all cases potted plants, plants growing in the laboratory, in the greenhouse, or otherwise under abnormal conditions, have been used. This work is an attempt to measure the loss of moisture under as nearly normal conditions as is possible with present day methods. The loss has not been considered as a "power of the leaf", but rather as a phenomenon over which it has no control. Water loss is due to external and internal environmental factors rather than a specific "ability" of the leaf "to give off water."

As far as the writer has been able to discover, very little work has been done in the way of a general survey of water

*Papers from the Department of Botany, Ohio State University, No. 215.

loss from leaves.* This is likely due to a lack of a practical quantitative method of determination, which can be carried into the field and used readily under natural conditions of the many different habitats.

METHOD USED.

The cobalt chloride paper test was used, as devised by Stahl (19), improved by Livingston (9), Livingston and Shreve (10), and more recently by Sayre (12). Livingston's and Shreve's method was quite an improvement over that of Stahl, and has been used successfully by a number of workers. However, it should be noted, that the results obtained by this method are entirely qualitative and relative.

To secure quantitative results Sayre (12) standardized cobalt chloride paper by the following method. Filter paper (Whatman No. 1) was saturated in a 3% solution of cobalt chloride, dried in an oven until the blue color appeared, and then continued in a desiccator containing anhydrous calcium chloride. Dry weight was then obtained, after which they were placed in a moist chamber and left until they attained a full pink color, and reweighed. The difference in weight represented the amount of water vapor necessary to change the blue paper to a full pink color.

From these data it is seen that if the cobalt paper is properly applied to a leaf surface the actual water loss can be obtained. A number of investigators have used small glass plates to cover the cobalt papers in protecting from atmospheric moisture, and to hold the papers in place on the leaf to be tested. Sayre (12) used celluloid instead of glass. The cobalt paper was cut in circular areas with a punch $1\frac{5}{32}$ " in diameter. The celluloid was cut in strips $\frac{3}{8}$ " x $1\frac{1}{2}$ ". The cobalt paper was then fastened at each end and on the same surface of the strips by means of gummed reënforcements for notebook paper. These were of greater diameter than the width of the strips, so extended over the sides and end. A reënforcement was moistened and applied near one end of the strip, the perforation being covered by the celluloid. While still moist the strip

*The following workers have contributed to our knowledge of water loss from various species: Livingston (9), Shreve (17), Trelease (20), Meyer (12 and 13), Shive and Martin (16), Cribbs (4 and 5), McGinnis and McDougall (11), Bakke (1 and 3), Delf (6), Kiesselbach (8), Rosenberg (15), and others. With the exception of Kiesselbach, these workers used Stahl's (19) Cobalt Chloride Method, the same as improved by Livingston (9), Livingston and Shreve (10) and by Sayre (12).

was inverted, cobalt paper placed opposite the perforation in reenforcement and a dry reenforcement placed over the paper so that the dry gummed surface was in contact with the moist gummed surface projecting over the edges. The gummed surfaces were pressed tightly together. These held the cobalt paper in position with only the one surface exposed, which was to be placed next to the leaf, and the other surface could be seen through the celluloid. After cobalt paper was attached to both ends of strip in the above manner, the strip was folded along the short axis through the center. This then made a clip which could be readily clamped on a leaf with a hygrometric paper exposed to each surface. In this work the clips were attached to a leaf surface by means of small clamps (Denison Card Holder, No. 42). The hook at the end was convenient for attaching a slip of paper with number of the leaf and time at which the clip was applied. Fifty or sixty clips were made so that time would not be lost in waiting for them to dry in a desiccator. The clips were kept in desiccators made of wide-mouthed bottles, of convenient size for carrying, with anhydrous calcium chloride. These clips were used until they became soiled or wet. The desiccating process can be greatly speeded up by placing the bottles in bright sunlight or near a fire. As color standards, a paper may be kept in a small desiccator for the blue color. For the pink standard a clip which has been in contact with a leaf surface until a full pink color has appeared, may be carried about on a leaf, or in a bottle.

The paper used in collecting the data given below was standardized to .05981 gram of water per 100 square centimeters. That is, it took .05981 gram of water to change the blue (dry) cobalt chloride paper to a full pink color. So, if it takes 1 minute to change the blue to pink, the grams of water vapor absorbed per 100 square centimeters in one hour would be 60 times .05981 gram. Meyer's (12) formula was used in making the calculations. It is as follows:

$$\frac{.05981 \times 3600 \text{ (Sec. in one hour)}}{T \text{ (Time of color change)}} = G \text{ (Grams of water vapor).}$$

In each case the wet and dry bulb temperatures were taken in order that the relative humidity might be determined. The thermometers were kept in a shaded place as near the leaves being tested as was possible. Shreve (17) showed that temperature of the air immediately surrounding the leaf may

be safely used instead of the temperature of the clip itself. Leaves in good condition as far as could be determined were selected in every case except where indicated. In practically all cases five readings were taken at a single time, each on different leaves, and the time of color change averaged for each surface. So that in the following lists and graphs the time of color change indicated is an average for a given surface, and not for a single leaf or a single reading. The time of change has also been standardized for a temperature of 20 degrees C. In doing this Livingston's and Shreve's (10) table was used.

Bakke (1) pointed out the fact that the only external environmental factor directly affecting water loss from a leaf surface by cobalt chloride paper is temperature. This can be standardized to a given degree by Livingston's and Shreve's (10) table.

The relative humidity may have an effect through the layer of air imprisoned between the leaf surface and the cobalt paper. This effect must be very small since the moisture in this layer is absorbed almost instantly and the relative humidity is 0 in a very short time after the clip is applied.

The direct effect of light is small since but little light can pass through the cobalt paper. The relative humidity and light intensity may have a far reaching indirect effect. The direct effect of air currents is also removed. Some of the other factors which may have effect upon water loss have been pointed out by Kiesselbach (8) and Cribbs (4 and 5).

The cobalt chloride method of measuring water loss measures the water vapor given off at a particular instant, and is not measuring accumulative quantities, as does the potometer method. For this reason it is not safe to compare the two means of determination. In the potometer method light, relative humidity and wind have a direct effect on the amount of water lost. Because of these differences Dr. E. N. Transeau suggested to the writer the term "Standard Water Loss" from the leaf surface, as being the water loss measured by the cobalt chloride method.

The chief sources of error in the cobalt chloride method are:

1. The hygrometric paper absorbs some moisture from the atmosphere during transfer from the desiccator to the leaf. In every case this transfer was accomplished as quickly as possible, and took but a few seconds.

2. There may be a source of error in determining when to take the reading. This difficulty may be, at least partly, removed by having color standards as suggested.

3. Lateral leakage from surrounding air may also be a source of error. This error seems to be quite small, for in a number of instances, usually on upper surfaces, the test papers remained unchanged for two hours.

4. Pressure of the clip on the leaf surfaces may cause some change in size of the opening of the stomata.

5. Average leaves may not be selected for the tests. However, as tests were made on five leaves each time and an average taken for the standard water loss, it is believed that most of this source of error is removed.

MEASUREMENTS OF WATER LOSS.

Standard water loss data was collected on the following 123 species during the fall of 1925, spring, summer and fall of 1926. Excepting tests for diurnal rates, all readings were taken between the hours of 10:00 A. M. and 1:30 P. M. during which time the stomata were expected to be open and the maximum rate of standard loss taking place. As some of the series of readings later showed, this is not always the case. The maximum rate sometimes occurred early in the day, as shown by the diurnal study. Shreve (18) found this to occur among some desert species. Although the readings do not necessarily represent the maximum rate of standard water loss, they still retain a certain value as a survey.

This list contains plants from a wide range of environmental conditions. Some examples are as follows:

Sphagnum Bog—*Vaccinium*, *Menyanthes*, *Sarracenia*, *Decadon*, *Alnus*, *Hibiscus*, and *Rhus Vernix*; Swamp—*Cephalanthus*, *Sium*, *Quercus palustris*, *Rosa carolina*, *Ilex*, *Alisma*, *Iris*, *Glyceria*, *Impatiens*, etc.; Aquatic—*Polygonum amphibium*, *Typha*, *Sagittaria*, *Dianthera*, etc.; Flood plain—*Salix*, *Aesculus*, *Allium*, *Angelica*, *Arctium*, *Asimina*, *Celtis*, *Prunus* and *Urtica*; River Bank—*Ambrosia*, *Elymus*, *Platanus*, etc.; Talus slope—*Sambucus racemosa*, *Epigea*, *Epipactus*, *Gaulthera*, *Cypripedium*, *Rhododendron* and *Betula*; Ledge—*Sullivantia* and *Polypodium*; Plains—*Buchloe*; Prairies—*Silphium laciniatum*; Agricultural plants—*Zea*, *Solanum tuberosum*, *Bromus*, and *Phleum*; "Weeds"—*Amaranthus*, *Xanthium*, *Chenopodium*, *Convolvulus*,

Abutilon, *Lactuca*, *Arctium*, *Setaria*, *Digitaria*, *Taraxacum*, *Polygonum virginianum*, *Leonurus*, *Erigeron*, *Cirsium*, and *Ambrosia*.

TABLE I.
MEASUREMENTS OF WATER LOSS.

NAME OF PLANT	Date	Temp. of air in Degrees C.	Av. No. of Secs. for Upper Surface	Av. No. of Secs. for Lower Surface	Corrections made for Temp. (Upper)	Corrections made for Temp. (Lower)	Grs. of Water Lost Per Hour (Upper)	Grs. of Water Lost Per Hour (Lower)	Time of Reading	Relative Humidity
<i>Abies Cilicica</i> Carr.....	4-21'26	17.7	824	1360	716.5	1182.6	.3*	.182	12:30	41
<i>Abutilon Theophrasti</i> Medic....	6-25'26	26.9	158	44	239.3	66.6	.89	3.23	11:40	52
<i>Acer platanoides</i> L.....	10-15'25	14.4	1605	247	1132.3	173.9	.18	1.23	12:30	89
<i>Acer rubrum</i> L.....	7-16'26	26.6	1780	116	2656.7	173.1	.081	1.243	12:30	56
<i>Acer saccharinum</i> L.....	10- 8'25	14.4	1995	150	1404.9	105.6	1.532	2.038	12:25	62
<i>Acer saccharum</i> L.....	5-19'26	18.0	2940	1344	2601.7	1189.3	.082	.181	11:40	82
<i>Aesculus glabra</i> Willd.....	5-25'26	18.6	3624	2004	3324.7	1838.5	.0647	.117	12:35	89
<i>Argopyron repens</i> (L.) Beauv..	7-14'26	24.4	76	89	98.7	115.5	2.181	1.864	12:49	43
<i>Alisma Plantago-aquatica</i> L....	6- 1'26	26.6	60	60	65.9	65.9	3.267	3.267	12:55	75
<i>Allium Tricoccum</i> Ait.....	4-10'26	13.3	642	383	419.6	250.3	.513	.862	12:11	55
<i>Alnus rugosa</i> (Du Roi) Spreng.	7-15'26	23.8	.....	840	.....	1063.2	.....	.202	11:40	58
<i>Ambrosia trifida</i> L.....	7-14'26	19.4	168	95	161.5	91.3	1.333	2.358	10:45	67
<i>Amaranthus retroflexus</i> L.....	6-26'26	26.1	47	49	68.1	71	3.162	3.032	12:05	57
<i>Angelica atropurpurea</i> L.....	5- 6'26	26.6	589	59	879	88	.244	2.446	1:25	35
<i>Arctium minus</i> Bernh.....	5-31'26	24.7	474	108	632	144	.3406	.149	11:50	83
<i>Asimina triloba</i> Dunal.....	8- 6'26	28.6	1440	125	2400	208.3	.0897	1.033	10:20	80
<i>Aspidium cristatum</i> (L.) Sw....	6-19'26	19.44	492	177	473	170.1	.455	1.265	11:45	67
<i>Aspidium marginale</i> (L.) Su....	4-10'26	14.1	2322	1564	1601.3	1078.5	.134	.199	11:05	46.5
<i>Barbarea vulgaris</i> R. Br.....	4-14'26	17.7	149.3	97.5	131.1	85.5	1.642	2.518	12:00	9
<i>Berberis thunbergii</i> D. C.....	7- 3'26	30.0	1428	402	2596.3	730.9	.082	.294	11:52	58.5
<i>Betula lenta</i> L.....	7- 8'26	25.2	520	38.3	712.2	52.4	.302	4.10	12:05	77
<i>Bromus inermis</i> Leyss.....	7- 1'26	31.1	955	3172	1836.3	6100	.117	.035	12:35	39.5
<i>Buchloe dactyloides</i> (Nutt)										
<i>Engelm</i>	7-12'26	26.1	1745	1745	2528.9	2528.9	.085	.085	10:33	54
<i>Cannabis sativa</i> L., (Male).....	8-26'26	25.2	868	88	1189	120.5	.0181	1.786	11:30	75
<i>Cannabis sativa</i> L. (Female)....	8-26'26	25.2	570	91	780.8	124.6	.0275	1.728	11:30	75
* <i>Carica papaya</i> Linn.....	7-20'26	34.4	.....	662	.....	1539.5	.....	.167	10:45	39
<i>Castanea dentata</i> (Marsh) Borkh.	7- 8'26	26.3	520	296.6	764.7	436.4	.281	.493	12:55	71
<i>Catalpa bignonioides</i> Walt.....	7-13'26	20.5	2116	311	2181.4	320.6	.0987	.671	11:45	74
<i>Celtis occidentalis</i> L.....	8- 6'26	29.7	1338	132	2389.2	235.7	.09	.913	11:00	81
<i>Cephalanthus occidentalis</i> L....	6-22'26	23.3	1608	37	1960.9	45.1	.109	4.774	11:15	64
<i>Chenopodium album</i> L.....	6-25'26	28	150	128	241.9	206.4	.89	1.04	12:13	49
<i>Cirsium arvense</i> (L.) Scop.....	6-24'26	27.2	518	60	796.9	92.3	.271	2.33	11:30	51
<i>Comvolvulus sepium</i> L.....	6-25'26	28.6	130	146	216.6	243.3	.994	.884	1:15	40
<i>Corylus americana</i> Walt.....	6-23'26	26.3	1614	59	2375	86.7	.090	2.43	12:15	52
<i>Crataegus</i> sp.....	5-13'26	18.8	2400	104	2242.9	97.1	.095	2.21	12:30	87
<i>Cypripedium hirsutum</i> Mill.....	7- 9'26	26.9	339	71	513.6	107.5	.419	2.002	11:20	85
<i>Decadon verticillatus</i> (L.) Ell...	7-15'26	25.2	2755	77	3773.9	105.4	.057	2.042	12:55	60
<i>Dianthera americana</i> L.....	7-14'26	20.83	92	181	96.8	190.5	2.22	1.13	10:23	57.5
<i>Digitaria sanguinalis</i> (L.) Scop.	6-25'26	27.7	924	304	1466.6	482.5	.146	.446	2:30	46.5
<i>Elymus virginicus</i> L.....	7-22'26	37.2	475	.....	1283.7	.....	.167	.....	12:05	43.5
<i>Epigaea repens</i> L.....	7- 9'26	26.6	155	64	231.3	95.5	.930	2.25	11:20	87

*Growing in Greenhouse.

TABLE I—Continued.

NAME OF PLANT	Date	Temp. of air in Degrees C.	Av. No. of Secs. for Upper Surface	Av. No. of Secs. for Lower Surface	Corrections made for Temp. (Upper)	Corrections made for Temp. (Lower)	Grs. of Water Lost Per Hour (Upper)	Grs. of Water Lost Per Hour (Lower)	Time of Reading	Relative Humidity
<i>Epipactis</i> sp.....	7- 9'26	27.7	500.6	66	794.6	104.7	.270	2.05	12:50	70
<i>Equisetum arvense</i> L.....	7- 1'26	30.2	98	250	181.4	462.9	1.175	.465	12:15	34
<i>Erigeron annuus</i> (L.) Pers.....	6-23'26	27.5	3372	2844	5268.7	4443.7	.040	.048	12:15	57.5
<i>Eupatorium perfoliatum</i> L.....	6-23'26	25	1884	47	2595.9	63.5	.084	3.39	1:10	56
<i>Fraxinus americana</i> L.....	10-14'25	13.3	2435	170	1591.5	111.1	.135	1.938	11:37	94
<i>Gaultheria procumbens</i> L.....	7- 9'26	26.6	943.3	71.6	1407.9	106.8	.152	2.016	10:13	87
<i>Gleditsia triacanthos</i> L.....	10-13'25	15.56	230	133	172.9	100	.1245	2.153	12:30	68
<i>Glyceria nervata</i> Trin.....	7- 2'26	30.28	50	672	92.4	1244.4	2.33	.173	12:55	48
<i>Glyceria septentrionalis</i> Hitchc.	7- 2'26	30.00	54	90	98.1	163.6	2.194	1.316	12:20	57
<i>Hepatica acutiloba</i> D. C.....	4-12'26	6.9	3121	947	1333.7	404.7	.161	.532	1:38	70
<i>Hibiscus moscheutos</i> L.....	7-15'26	23.89	.....	168	.....	212.6	.....	1.012	11:26	58
<i>Ilex verticillata</i> (L.) Gray.....	6-19'26	19.4	2652	128	2550	123	.084	1.75	.....	67
<i>Impatiens biflora</i> Walt.....	7- 2'26	30.56	54	33	101.8	62.2	2.115	3.46	12:05	60.5
<i>Iris versicolor</i> L.....	6-22'26	23.6	45	56	56.2	70	3.83	3.075	11:30	60.5
<i>Juglans nigra</i> L.....	7- 3'25	30.8	2460	1116	4641.5	2105.6	.046	.102	12:25	54
<i>Kalmia latifolia</i> L.....	7- 9'26	26.6	788.3	63.6	1776.5	94.7	.121	2.273	10:00	87
<i>Lactuca scariola integrata</i> Gren. and Godr.....	6-21'26	25.8	1212	165	1731.4	235.7	.124	.913	10:30	64
<i>Leersia oryzoides</i> (L.) Su.....	7-22'26	27.7	607	93	963.4	147.6	.223	1.458	10:15	78
<i>Leonurus cardiaca</i> L.....	6-21'26	26.1	1818	203	2634.7	294.4	.081	.731	10:50	64
<i>Loniceria</i> sp.....	5-14'26	17.2	1644	59	1381.5	49.5	.155	4.349	12:20	72
<i>Lysimachia nummularia</i> L.....	4-15'26	4.4	1103	509	396.7	183	.542	1.176	12:10	61
<i>Malva rotundifolia</i> L.....	10- 7'25	23.06	365	123	439.7	148.1	.4896	1.453	1:05	65
<i>Maclura pomifera</i> (Raf.) Schn.	8- 6'26	31.6	1572	58	3144	116	.068	1.856	12:31	65
<i>Menyanthes trifoliata</i> L.....	7-16'26	23.33	320	84	390.2	102.4	.551	2.102	10:05	72
<i>Mitchella repens</i> L.....	4-13'26	8.8	3492	632	1695.1	306.7	.127	.702	12:40	53
<i>Nepeta cataria</i> L.....	4-14'26	17.7	392	137	340.8	119.1	.631	.180	12:15	9
<i>Nepeta hederacea</i> (L.) Trevisan	4- 7'26	17.5	908	92	776	78.6	.277	2.739	12:25	61
<i>Oenothera biennis</i> L.....	6-21'26	26.9	1020	958	1545.4	1451.5	.139	.148	11:15	61.5
<i>Ophioglossum vulgatum</i> L.....	6-30'26	28.3	370	142	606.5	232.1	.355	.927	10:30	66
<i>Osmunda cinnamomea</i> L.....	7-16'26	25.8	872	101	1245.7	144.2	.172	.149	12:20	53.5
<i>Pastinaca sativa</i> L.....	10-23'25	15.00	667	102	486.8	74.4	.442	2.89	12:15	39
<i>Phleum pratense</i> L.....	7-14'26	23.89	138	143	174.6	181	1.233	1.189	12:40	48
<i>Picea Abies</i> (L.) Karst.....	4-27'26	12.2	1402	1402	854	854	.252	.252	12:45	43
<i>Pinus austriaca</i> Hoss.....	5-19'26	17.78	261	261	226.9	226.9	.948	.948	12:20	79
<i>Pinus contorta</i> Dougl.....	4-23'26	18.8	252	210	233.3	185.1	.9229	1.163	12:30	58
<i>Pinus rigida</i> Mill.....	4-24'26	14.4	255	286	179.5	201.4	1.199	1.069	12:30	72
<i>Pinus strobus</i> L.....	4-23'26	18.8	882	890	816.6	824.1	.2636	.261	11:50	58
<i>Pinus sylvestris</i> L.....	4-20'26	13.3	892	988	583	645.7	.369	.333	12:30	32
<i>Plantago lanceolata</i> L.....	10- 8'26	14.4	66	71	464	50	.464	4.306	12:22	62
<i>Plantago major</i> L.....	10- 8'25	14.4	121.6	60	85.6	42.2	2.503	5.102	12:50	62
<i>Platanus occidentalis</i> L.....	8- 6'26	31.3	1434	64	2811.7	125.4	.076	1.717	11:58	64
<i>Polygonum amphibium</i> L.....	7-15'26	22.7	50	50	58.8	58.8	3.661	3.661	11:15	58
<i>Polygonum virginianum</i> L.....	7-12'26	28.8	2675	124	4533.8	210.1	.047	1.024	12:45	70
<i>Polypodium vulgare</i> L.....	4-10'26	13.8	3459	1563	2337.1	1056	.092	.203	12:45	51.5
<i>Polystichum acrostichoides</i> (Michx.).....	4-12'26	6.9	4615	726	1972.2	310.2	.109	.694	1:32	71
<i>Polytrichum ohioense</i> R. & C...	7- 2'26	30.5	25	25	47.1	47.1	4.571	4.571	12:40	42.5
<i>Populus deltoides</i> Marsh.....	10-15'25	15.0	455	210	332.1	145.9	.648	1.475	12:15	89
<i>Potentilla canadensis</i> L.....	6-23'26	26.1	493	33	714.3	47.8	.301	4.504	12:50	48
<i>Prunus serotina</i> Ehrh.....	5- 7'26	27.7	.....	130	.....	206	.....	1.045	12:10	31

TABLE I—Continued.

NAME OF PLANT	Date	Temp. of air in Degrees C.	Av. No. of Secs. for Upper Surface	Av. No. of Secs. for Lower Surface	Corrections made for Temp. (Upper)	Corrections made for Temp. (Lower)	Grs. of Water Lost Per Hour (Upper)	Grs. of Water Lost Per Hour (Lower)	Time of Reading	Relative Humidity
<i>Quercus bicolor</i> Willd.....	6-18'26	25.2	1812	876	2482.1	1200	.086	.179	11:45	77
<i>Quercus palustris</i> Muench.....	6-23'26	26.1	1848	112	2678.2	162.3	.080	1.326	12:00	57
<i>Rhododendron maximum</i> L.....	7- 7'26	22.2	1956	105.6	2248.2	121.3	.095	1.775	10:20	86
<i>Rhus Vernix</i> L.....	7-15'26	24.4	3001	282	3897.3	366.2	.055	.587	12:32	48
<i>Rosa carolina</i> L.....	6-17'26	29.4	1515	60	2657.8	105.2	.081	.204	1:00	63
<i>Rubus occidentalis</i> L.....	5-20'26	16.9	4020	93	3322.3	77.6	.064	2.774	12:45	62
<i>Rumex altissimus</i> Wood.....	7-12'26	28.6	206	133	343.2	221.6	.627	.971	12:30	72
<i>Sagittaria</i> sp.....	6- 1'26	22.2	112	82	128.7	94.2	1.673	2.285	12:40	73
<i>Salix babylonica</i> L.....	10-14'25	13.8	1585	171	1070.9	115.5	.201	1.864	12:30	100
<i>Salix discolor</i> Muhl.....	6-18'26	22.5	92.8	53.2	107.9	61.8	1.995	3.484	12:00	63
<i>Salix nigra</i> Marsh.....	7-22'26	29.1	172	60	296.5	103.4	.726	2.082	11:00	70
<i>Sambucus canadensis</i> L.....	6-22'26	23.6	3084	44	3855	55	.055	3.914	11:45	58.5
<i>Sambucus racemosa</i> L.....	7- 7'26	25.2	2520	2136	3452.1	2926	.0623	.735	12:45	58
<i>Sarracenia purpurea</i> L.....	7-16'26	23.3	512	454	624.3	553.6	.344	.388	10:20	66
<i>Setaria italica</i> (L.) Beauv.....	7-14'26	21.9	960	1331	1078.6	1495.5	.199	.143	12:00	54
<i>Silphium laciniatum</i> L.....	7-12'26	25.2	113	124	154.7	169.8	1.391	1.268	10:10	54.5
<i>Silphium perfoliatum</i> L.....	7- 1'26	29.4	1788	1200	3136.8	2105.2	.068	.102	11:20	41.5
<i>Sium ciculaefolium</i> Schrank.....	6-18'26	22.2	312	60	358.6	68.9	.600	3.125	11:05	69
<i>Solanum Dulcamara</i> L.....	10-24'25	15.0	.....	483	.....	352.5	.....	.610	12:30	39
<i>Solanum tuberosum</i> L.....	6-26'26	26.6	235	258	350.7	385	.613	.559	10:45	54
<i>Sullivantia Sullivantii</i> (T. & G.) Britton.....	7- 8'26	25.5	615	180	8541	250	.025	.845	11:45	78
<i>Taraxacum officinale</i> Weber....	7- 3'26	31.1	612	92	1176.9	176.9	.182	1.217	1:15	52
<i>Typha angustifolia</i> L.....	7-16'26	25.5	115	216	159.7	300	1.348	.717	11:30	64
<i>Typha latifolia</i> L.....	5-31'26	26.6	64	52	95.5	77.6	2.254	2.774	12:30	83
<i>Ulmus americana</i> L.....	10-13'25	13.8	1330	130	904.7	88.4	2.379	2.435	12:12	77
<i>Urtica gracilis</i> Ait.....	5-20'26	16.6	2076	66	1674.1	53.2	.128	4.047	1:15	64
<i>Vaccinium macrocarpon</i> Ait....	7-16'26	26.6	635	108	947.7	161.2	.227	1.335	12:50	54
<i>Verbascum Thapsus</i> L.....	8-25'26	5.5	1237	455	479.4	176.3	.449	1.221	1:15	92
<i>Vinca minor</i> L.....	3-24'26	16.1	4152	203	3243.7	158.5	.066	1.358	12:11	77
<i>Vitis cordifolia</i> Michx.....	5-26'26	20.5	42	384	43.2	395.8	4.984	.544	1:00	55
<i>Xanthium</i> sp.....	7-14'26	25.0	91	63	122.9	85.1	1.751	2.530	1:04	41
<i>Yucca</i> sp.....	3-29'26	9.7	4130	3702	2128.8	1908.2	.1011	.1128	1:28	58.5
<i>Zea mays</i> L.....	6-25'26	24.1	139	122	178.2	156.4	1.208	1.376	10:30	61

A study was made of the standard loss from evergreen plants. The readings were taken before growth had started in the spring. The leaves were approximately one year old.*

*The averages which follow were obtained first by averaging the standard loss for the upper and lower surfaces of the leaves as given in the above list of plants (i. e. these quantities of water vapor represent the sum of the loss from 50 sq. cm. of upper surface and 50 sq. cm. of the lower surface). Then these averages were averaged for the following groups.

I. SPERMATOPHYTES.

A. Gymnosperms.

1. *Abies Cilicica*

2. *Picea abies*

3. *Pinus austriaca*

4. " *contorta*

5. " *rigida*

6. " *strobus*

7. " *sylvestris*

The average standard loss for this group was .5481 gm. The greatest loss was from *P. rigida*—1.134 gm. The smallest was from *A. Cilicica*—.241 gm.

B. Angiosperms—(Leaves had passed through the winter. Exact age was not known.)

1. *Barbarea vulgaris*

2. *Lysimachia numularia*

3. *Mitchella repens*

4. *Nepeta Cataria*

5. *Nepeta hederacea*

6. *Verbascum Thapsus*

7. *Vinca minor*

8. *Yucca* sp.

The average for the group was .8523 gm. *Barbarea* was highest—2.08 grams, and *Yucca* was lowest—.1065 gm.

II. PTERIDOPHYTES.

1. *Aspidium marginale*

2. *Polypodium vulgare*

3. *Polystichum acrostichoides*

The average for the group was .2401 gm. *Polystichum* was highest—.4015 gm. *Polypodium* lowest—.1525 gm.

Some readings were taken on a sugar maple and two pines growing near one another. The readings were taken within one hour and on the same day. The maple leaves were approximately 20 days old and the pine leaves about 1 year old. The results are as follows:

<i>Acer saccharum</i>	.104 gm.
<i>Pinus sylvestris</i>	.110 "
<i>Pinus austriaca</i>	.948 "

In order to get a comparison between the standard loss for corn, the potato and some common "weeds," growing along beside the corn and potato, the following data were collected:

1. *Abutilon Theophrasti*.....

2. *Amaranthus retroflexus*.....

3. *Chenopodium album*.....

4. *Convolvulus sepium*.....

5. *Digitaria sanguinalis*.....

6. *Setaria italica*.....

7. *Xanthium* sp.....

8. *Solanum tuberosum*.....

9. *Zea mays*.....

2.065 grams

1.848 "

2.889 "

2.132 "

.295 "

.171 "

2.14 "

1.361 "

1.786 "

McGinnis and McDougal (11) made a number of similar comparisons of several "weeds" with corn, using the cobalt chloride method as developed by Livingston and Shreve (10). Their plants were of necessity grown in the greenhouse and data were obtained during the months of February, March and April. The writer took a series of readings in August on a single *Zea* plant and a similar series simultaneously on an *Amaranthus* plant, growing near the corn. Fig. 1 shows the results graphically.

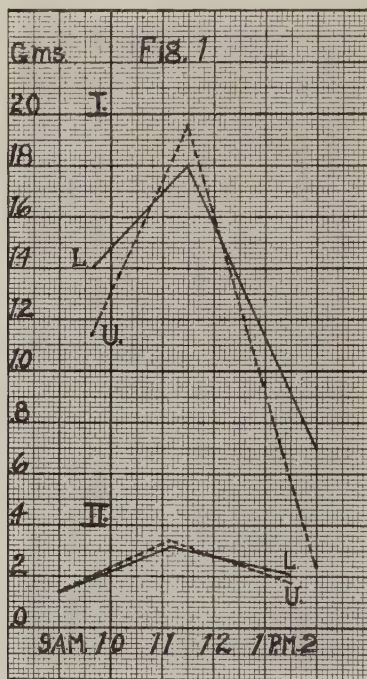


Fig. 1. I. Graph showing the standard water loss for the upper (U) and lower (L) surfaces of *Amaranthus retroflexus* leaves. II. Graph showing the standard water loss for the upper (U) and lower (L) surfaces of *Zea mays* leaves. Readings on both plants were taken simultaneously.

An effort was made to test out the difference in standard loss of rolled and non-rolled leaves of the same species. The two bunches of *Elymus virginicus* selected were growing within a few feet of each other on a river bank. One bunch showed rolled leaves and the other did not. The leaves tested were not on the same plant but on different plants in each cluster. The results are as follows:

Rolled leaves were losing..... .167 gram
 Unrolled leaves were losing..... .1.696 grams

Bakke and Livingston (3) pointed out the fact that water loss is different for leaves occupying different positions on the same plant. This has been confirmed in the case of a large specimen of *Ulmus americana*. Readings were taken at an altitude of approximately 40 feet, and others on leaves which could be reached while standing on the ground. The lower readings were started at 11:45 and the upper at 12:00. The leaves were more or less shaded in both positions. The tests were made in August. The tree apparently had an abundant water supply as it was growing on a river bank. No satisfactory color change was obtained in either upper surface. In the upper position only one paper changed color on the lower surface after an exposure of 50 minutes. The other papers were left on for 1 hour and 20 minutes without change. In the lower position, papers on the lower surfaces changed in the average time of 38 minutes 24 seconds. The standard water loss was .0401 gm. per 100 square centimeters in one hour at a temperature of 20 degrees C. Calculations for the upper position were not made because of unsatisfactory color change. The rate for the leaves in the higher position was evidently much lower.

A number of readings were taken simultaneously on young and mature leaves in order to get a comparison. The results were as follows:

	YOUNG	MATURE
1. <i>Silphium perfoliatum</i>	.2085 gm.	.788 gm.
2. <i>Corylus americana</i>	.285 "	1.2865 "
3. <i>Arctium minus</i>	.5235 "	3.5955 "
4. <i>Cephalanthus occidentalis</i>	.193 "	1.239 "
5. <i>Chenopodium album</i>	.9665 "	2.8895 "
6. <i>Convolvulus sepium</i>	.939 "	2.1325 "
7. <i>Sarracenia purpurea</i>	.118 "	.732 "
8. <i>Typha latifolia</i>	4.816 "	2.51 "

It is interesting to note that *Typha latifolia* is the only species examined in which the young leaves were simultaneously losing more water than the mature leaves. Meyer (13) has been able to express more juice from mature leaves than from young.

A series of readings were made on *Acer saccharum*, *Rosa carolina* and on *Catalpa bignonioides*, at certain intervals during the summer. The leaves were marked when the first reading was made. The same leaves were tested each time, excepting in the last reading on the *Acer* all the marked leaves had dis-

appeared except two. Others were selected which were approximately in the same position. Also all but one of the tagged leaves of *Rosa* had disappeared by the time of the second reading.

The readings on *Rosa* were made first on May 17, and showed a standard loss of .933 gm. One month later, at the same time of day, readings were again taken. The loss then was .141 gm., showing a decrease of .792 gm. per unit area for the more mature leaves.

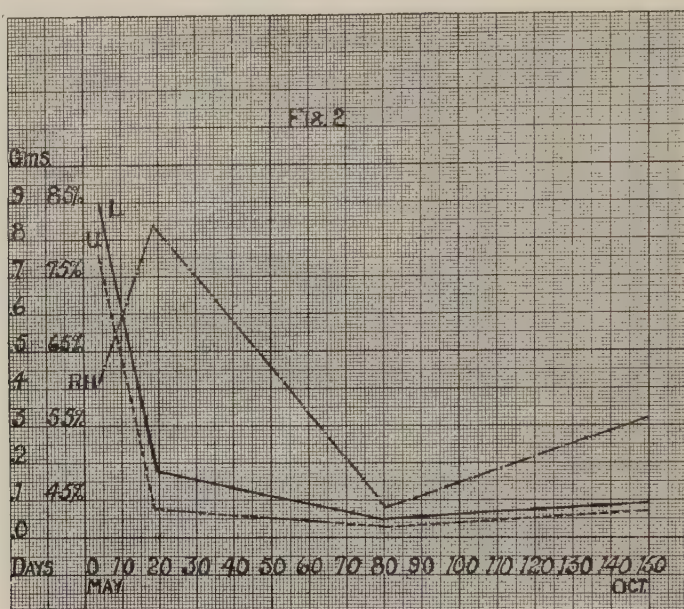


Fig. 2. Graph showing standard water loss from leaves of *Acer saccharum* from the time they were unrolling from the buds until they were approximately 150 days old. L, lower surface. U, upper surface. R. H., relative humidity.

On July 13 the first readings were taken on *Catalpa*. The loss was found to be .4475 gm. On August 31 readings were again taken on the same leaves at the same time of day. The result obtained this time was .2559 gm., or .1916 gm. decrease for the older leaves.

On May 4 readings were started on *Acer saccharum*. The leaves were just unrolling at this time. Three other readings were taken during the summer and autumn. The graph, Fig. 2, shows the results.

While working with very young leaves it was found that several, notably *Convolvulus*, *Psedera quinquefolia* (L) Greene

and *Vitis cordifolia* Michx. lost water more rapidly along the midrib than on the remainder of the leaf. This was determined by the fact that a pink streak appeared in the cobalt paper which was directly over the midrib or a large vein. The remainder of the paper continued blue for some time.

Starting at 12:45 P. M., on July 7, a series of tests were made extending through 24 hours on *Sambucus racemosa*. The plant was growing on a talus slope, east exposure, very sandy soil, and protected by a high, cave-like cliff. There was a large spring a few feet away, so it likely had a plentiful

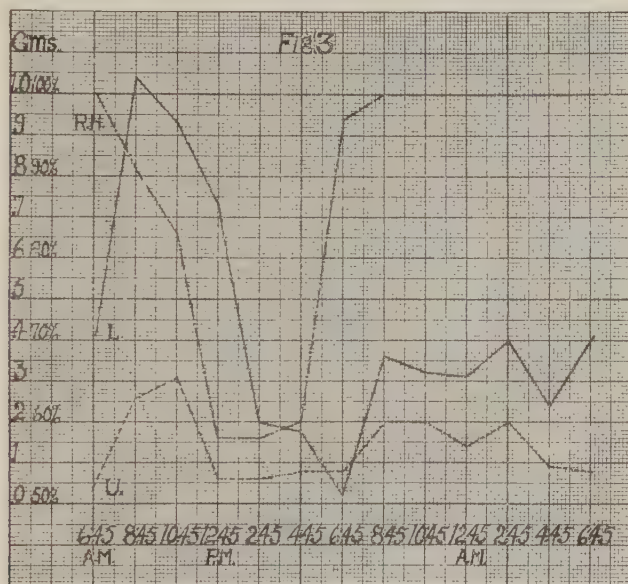


Fig. 3. Graph showing standard water loss for *Sambucus racemosa* during 24 hours. R. H., relative humidity. U, upper leaf surface. L, lower leaf surface.

water supply. The leaves were tagged and an area carefully marked on which the readings were taken each time. The readings were taken at two hour intervals. The results are graphically shown in Fig. 3.

Another series through 24 hours was obtained for *Catalpa bignonioides*. Readings were taken at intervals of 2 hours excepting from 7:45 A. M. to 3:45 P. M., during which time they were taken every hour. Five leaves, in apparently good condition, were selected and tagged as for *Sambucus*. Fig. 4 is a graph of the results obtained.

Peirce (14) states that many plants living in swamps and swampy places have constantly open stomata, and cites willows as a note-worthy example. Haberlandt (7) says "In many

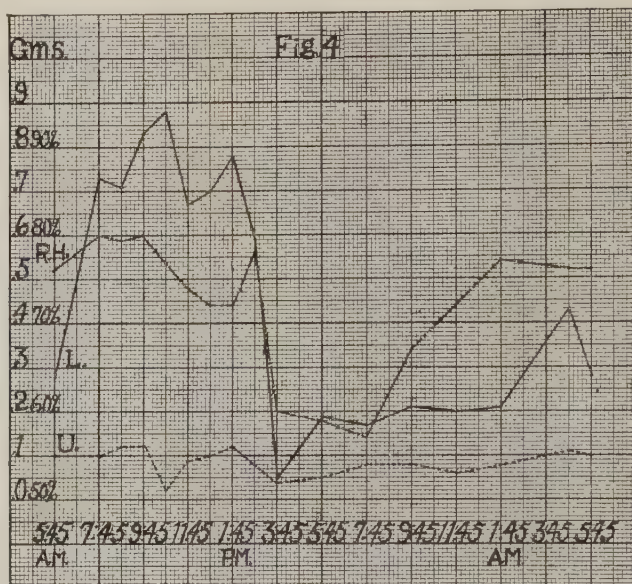


Fig. 4. *Catalpa bignonioides* standard water loss for 24 hours. R. H., relative humidity. U., upper leaf surface. L., lower leaf surface.

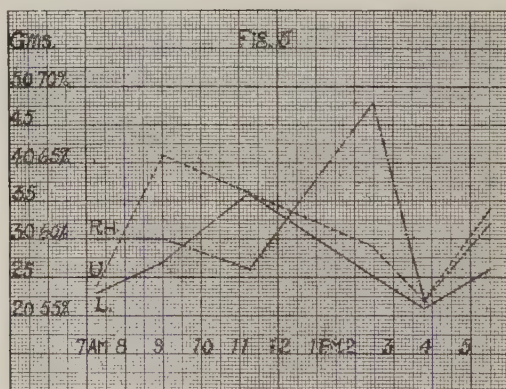


Fig. 5. *Polygonum amphibium* standard water loss. R. H., relative humidity. U., upper leaf surface. L., lower leaf surface.

plants the stomata lose their power of adjustment more or less completely, or at any rate become incapable of closing tightly after a certain age. This physiological degeneration of

the stomata takes place at a comparatively early age in floating and other aquatic plants, and also in a number of shade-loving hygrophytes." Delf (6) refers to such instances when considering Rosenberg's (15) work on the halophytes.

In order to investigate some of these aquatic and moist soil forms a series of readings were made, beginning first with *Polygonum amphibium*. The time of the readings range from 7:45 A. M. to 5:30 P. M., and were taken at two hour intervals.

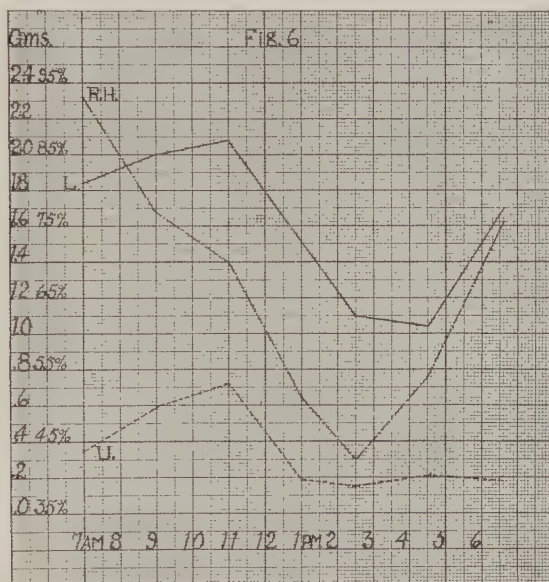


Fig. 6. *Salix nigra* standard water loss. R. H., relative humidity. U., upper leaf surface. L., lower leaf surface.

Fig. 5 shows the results. Series were taken on *Salix nigra*, *Dianthera americana*, *Hibiscus Moscheutos* and *Typha angustifolia*. The *Salix* and *Dianthera* were growing in water along the edge of a river; and the *Polygonum Hibiscus* and *Typha* were growing in water along the edge of a Sphagnum bog. Figs. 6, 7, and 8 respectively show the results.

SUMMARY AND CONCLUSION.

1. The data collected on the list of plants holds good only for the time and conditions listed. The time of day, age of plant, position of leaves, and habitat have a great deal to do with the standard loss. Other unknown factors may also cause a variation.

2. The average standard water loss for the whole list of 123 species, on which data was collected, is 1.15012 grams of water vapor in 1 hour for a leaf surface of 100 square centimeters. This and the following amounts are averages for both leaf surfaces.

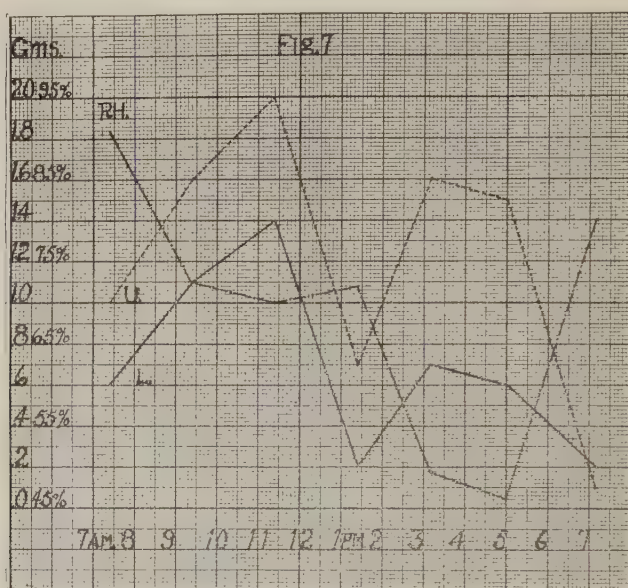


Fig. 7. *Dianthera americana* standard water loss. R. H., relative humidity. U., upper leaf surface. L., lower leaf surface.

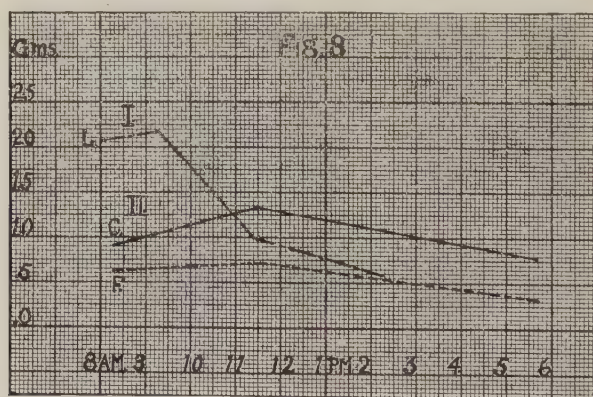


Fig. 8. I. *Hibiscus Moscheutos* standard water loss. Graph shows loss for lower surface only. II. *Typha angustifolia* standard water loss. C., curved surface. F., flat surface of leaves.

3. The average standard water loss, per hour for 100 square centimeters, for each group tested is as follows:

		No. Tested
I.	Spermatophytes.....	1.2146 gms..... 114
	A. Gymnosperms.....	.605 gm..... 7
	B. Angiosperms.....	1.2545 gms..... 107
	1. Grasses*.....	.8256 gm..... 11
II.	Pteridophytes.....	.4564 gm..... 7
III.	Bryophytes†.....	4.571 gms..... 1

4. The average rate of standard water loss for each of 8 associations is as follows:

		No. Tested
Swamp.....	1.9644 gms.....	10
Bog (acid).....	.6413 gm.....	9
Pond and Lake Margin....	2.2965 gms.....	4
River Margin.....	1.9395 gm.....	3
River Bank.....	.9413 gm.....	3
Flood Plain (mature).....	.7549 gm.....	8
Ledge association.....	.293 gm.....	2
Talus slope.....	1.2218 gms.....	8

5. The following plants showed the greatest standard loss:

<i>Polytrichum ohioense</i>	4.571 gms.
<i>Plantago major</i>	3.802 "
<i>Polygonum amphibium</i>	3.661 "
<i>Iris versicolor</i>	3.452 "
<i>Alisma Plantago-aquatica</i>	3.267 "

6. The following is a list of plants showing lowest water loss:

<i>Erigeron annuus</i> ‡.....	.04 gm.
<i>Juglans nigra</i>	.074 "
<i>Bromus inermis</i>	.076 "
<i>Elymus virginicus</i>	.083 "
<i>Buchloe dactyloides</i>	.085 "
<i>Silphium perfoliatum</i>	.085 "
<i>Aesculus glabra</i>	.09 "

7. Tests on evergreen leaves, before growth had started in the spring, showed the following results:

Angiosperms.....	.8523 gm.
Gymnosperms.....	.5481 "
Pteridophytes.....	.2401 "

*This includes swamp as well as plain form).

†*Polytrichum ohioense*, growing in a very moist location.

‡This plant was growing in a very dry location. Tests were made on another plant growing at the edge of a swamp. The soil was very wet. The standard loss in this instance was .37805 gm. per 100 sq. cm.

8. Tests for comparison between *Acer saccharum*, *Pinus austriaca* and *P. sylvestris*, under apparently the same external environmental conditions, showed that the year old pine needles were losing more water than the leaves of the maple which were about 20 days old.

9. Tests on *Abutilon*, *Amaranthus*, *Chenopodium*, *Convolvulus*, *Digitaria*, *Setaria*, *Xanthium*, *Solanum* and *Zea*, all growing near one another in the same field, showed an average standard loss of 1.631 gms. The average for the weeds alone was 1.6485 gms. This includes *Digitaria* and *Setaria* which are very slow water losers. The average for the corn and potato was 1.5735 gms.

10. Graphic results of a series of readings on *Amaranthus* and *Zea*, growing side by side, shows that the pigweed loses nearly 6 times as much water as the corn per 100 square centimeters. This is just considering the maximum loss for each. The graph also shows that the time of maximum loss may vary for different species.

11. The following common "weeds," selected at random, showed an average standard loss of 1.1425 gms.: *Amaranthus*, *Xanthium*, *Chenopodium*, *Convolvulus*, *Abutilon*, *Lactuca*, *Arctium*, *Setaria*, *Digitaria*, *Taraxicum*, *Polygonum virginianum*, *Leonurus*, *Erigeron*, *Cirsium* and *Ambrosia*. Four agricultural plants showed a standard loss of 1.1085 gms. They were as follows: *Zea*, *Solanum tuberosum*, *Bromus* and *Phleum*.

12. Tests on rolled and unrolled leaves of *Elymus* showed that the unrolled leaves were losing over 10 times as much water as the leaves which were rolled.

13. Leaves of *Ulmus*, at an approximate altitude of 40 feet, were losing less water than those near the ground.

14. Very young leaves of *Silphium perfoliatum*, *Corylus*, *Arctium*, *Cephalanthus*, *Chenopodium*, *Convolvulus*, and *Sarracenia*, lose less water than mature leaves on which tests were made simultaneously. *Typha* showed a greater loss for the young leaves. The average standard loss for the group, including *Typha*, was 1.5735 grams for the young leaves and 1.8966 grams for the mature ones. In the instance of *Typha* the amount lost for the young leaves was 1.5825 grams per 100 square centimeters more than the total amount lost by the other seven species. Leaving *Typha* out of consideration, the mature leaves on the first seven species lost on an average of 3.916 times that of the young leaves.

15. A series of readings taken at different times during the spring, summer and autumn, on *Rosa*, *Catalpa*, and *Acer*, showed a decrease in the standard loss as the leaves grew older. At present the writer is unable to correlate these results with those obtained by simultaneous readings on young and mature leaves.

16. Young leaves of *Convolvulus*, *Psedera* and *Vitis*, showed a more rapid loss of water along the midrib and large veins than on other parts of the leaves. More mature leaves did not show this.

17. Series of readings running through 24 hours in the instances of *Catalpa* and *Sambucus*, and from 3 to 7 readings on *Polygonum amphibium*, *Salix nigra*, *Hibiscus*, *Dianthera*, *Typha angustifolia*, *Amaranthus* and *Zea*, showed that the maximum rate of water loss may occur at different times of day in different species. The series on *Polygonum*, *Salix*, *Hibiscus*, *Dianthera* and *Typha*, show that these water forms have a very decided rhythm in their water loss as do other forms tested, and that their rates of standard water loss varies within a wide range during the day.

18. More data, from many representatives of various groups and associations of plants, are needed before accurate generalizations can be made.

The writer wishes to express his very great appreciation and gratitude to Dr. E. N. Transeau, Dr. A. E. Waller, and Dr. J. D. Sayre of the Ohio State University, Department of Botany, for their help, advice, criticism and continued interest in this work. The same is expressed to Dr. C. E. O'Neal of the Ohio Wesleyan University, Department of Botany, and to others who have so kindly lent their services from time to time.

LITERATURE CITED.

1. BAKKE, A. L.
Studies on the Transpiring Power of Plants. Jour. of Ecology, 2:145-173, 1914.
2. ———
Determination of Wilting. Bot. Gaz. 66:81-116, 1918.
3. ——— and LIVINGSTON, B. E.
Further Studies on the Foliar Transpiring Power in Plants. Physiol. Res. 2:51-71, 1916.
4. CRIBBS, JAMES E.
Ecology of *Tilia americana*. I. Comparative Studies of the Foliar Transpiring Power. Bot. Gaz. 48:262-282, 1919.
5. ———
Ecology of *Tilia americana*. II. Comparative Studies of the Foliar Transpiring Power. Bot. Gaz. 49:289-313, 1921.

6. DELF, E. M.
Transpiration and Behavior of Stomata in the Halophytes. *Ann. Bot.* 25:485-505, 1911.
7. HABERLANDT, DR. E.
Physiological Plant Anatomy, pp. 474-475. Translated by Drummond, Montagu, from fourth German edition. Macmillan and Co., New York, 1914.
8. KIESSELBACH, T. A.
Transpiration as a Factor in Crop Production. *Res. Bull. No. 6*, Nebraska Agr. Exp. Sta., 1916.
9. LIVINGSTON, B. E.
The Resistance Offered by Leaves to Transpirational Water Loss. *The Plant World*, 16:1-35, 1913.
10. ——— AND SHREVE, EDITH B.
Improvements in the Method for Determining the Transpiring Power of Plant Surfaces by Hygrometric Paper. *The Plant World*, 19:287-307, 1916.
11. MCGINNIS, HELEN A. AND McDUGAL, W. B.
A Comparison of the Transpiration Rates of Corn and Certain Common Weeds. *Illinois State Academy of Science*, 16:82-88.
12. MEYER, BERNARD S.
The Measurement of the Rate of Water-Vapor Loss from Leaves under Standard Conditions. *Amer. J. Bot.* 14:582-591, 1927.
13. ———
Studies on Physical Properties of Leaves and Leaf Saps. *The Ohio Jr. Sci.*, 27:263-288, 1927.
14. PEIRCE, GEORGE JAMES.
The Physiology of Plants, p. 143. Henry Holt and Company, New York, 1926.
15. ROSENBERG, O.
Über die Transpiration der Halophyten. *Ofvers af Kongl. Vetenskap—Akad. Forhandlingar*, Stockholm, 1897. (Reviewed by Delf, E. F., *Ann. Bot.* 25:485-505, 1911.
16. SHIVE, J. W. AND MARTIN, W. H.
The Effect of Surface Films of Bordeaux Mixture on the Transpiring Power in Tomato Plants. *Plant World*, 20:67-86, 1917.
17. SHREVE, EDITH BELLAMY.
The Role of Temperature in the Determination of the Transpiring Power of Leaves by Hygrometric Paper. *The Plant World*, 22:172-179, 1919.
18. SHREVE, FORREST.
The Transpiration Power of Plants as Influenced by Differences of Altitude and Habitat. (*Abstract*) *Science*, N. S. 43:363, 1916.
19. STAHL, E.
Einige Versuche über Transpiration und Assimilation. *Bot. Zeit.* 52:117-146, 1894. (Reviewed by Livingston, B. E., *Plant World*, 19:287-309, 1916.
20. TRELEASE, S. F.
Foliar Transpiring Power of the Cocoanut. *The Philippine Journal of Science*, 20:167-176, 1922.

NEW BOOKS.

A COMPREHENSIVE MEMORANDUM ON SCIENTIFIC MANAGEMENT IN EUROPE

Has been issued as part of the documentation of the International Economic Conference, which began its sessions at Geneva on May 4. The document was prepared by the Economic and Financial Section of the League of Nations from information furnished to it by governments, by members of the Preparatory Committee for the Conference and by industrial organizations, which prepared memoranda at the request of members of the committee.

The salient phases of the subject and its international aspects are examined from this mass of information, and the statistical tables and summaries, as a consequence, are the most comprehensive, authentic and up-to-date available.

The memorandum is obtainable from the American agent for publications of the League of Nations, World Peace Foundation, 40 Mt. Vernon Street, Boston, Massachusetts. Price, \$.15.

